University of Alberta Library
0 1620 2911288 3

8

SCIENCE PROBLEMS

2

EX LIBRIS
UNIVERSITATIS
ALBERTENSIS

E. P. S. B.
STRATHEARN
JR. HIGH SCHOOL
LIBRARY BOOK
No. 1150

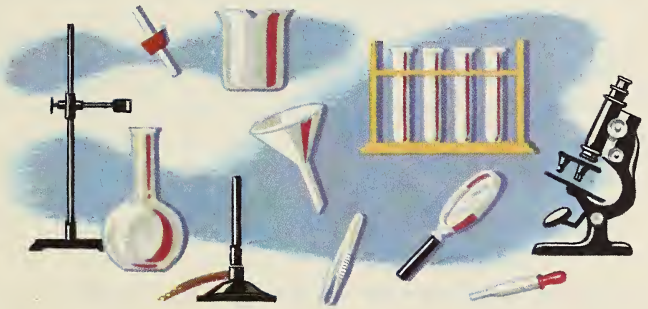
Digitized by the Internet Archive
in 2016 with funding from
University of Alberta Libraries

https://archive.org/details/scienceproblemsf00beau

BASIC STUDIES IN SCIENCE

Science problems 1

FOR JUNIOR HIGH SCHOOL



by Wilbur L. Beauchamp, John C. Mayfield, Joe Young West

SCOTT, FORESMAN AND COMPANY

Chicago, Atlanta, Dallas, San Francisco, New York

Contents

Unit 1 How do scientists think and work? 4
1 What kinds of problems do scientists solve? 8
2 How do scientists solve problems? 16
3 How do scientific instruments help scientists make discoveries? 23

Unit 2 What are the main groups of living things? 32
1 What groups of animals have backbones? 36
2 What groups of animals have no backbones? 43
3 What are the main groups of plants? 56
4 How do scientists classify living things? 68

Unit 3 What is a material? 78
1 How are all materials alike? 80
2 How are solids, liquids, and gases different from one another? 84
3 What is a solution? 88
4 How are materials put together? 95

Unit 4 How do heating and cooling change materials? 104
1 How do heating and cooling change the volume of materials? . 107
2 What changes of state are caused by heating materials? 116
3 What changes of state are caused by cooling materials? 126
4 How do heating and cooling change the action of molecules? .. 134

Unit 5 How can one material be changed into another? ... 142
1 What are materials made of? 146
2 How can we recognize a chemical change? 155
3 How can we control chemical changes? 164
4 How can we explain chemical changes? 171

Copyright, 1951, by Scott, Foresman and Company
Philippines Copyright, 1951, by Scott, Foresman and Company
Printed in the United States of America

UNIVERSITY LIBRARY
UNIVERSITY OF ALBERTA

Unit 6 How do we use and control fire? ... 178
1 What is fire? ... 182
2 How do we make a fire? ... 188
3 How can we prevent and extinguish fires? ... 204
4 How can we conserve fuel? ... 215

Unit 7 How do magnets work? ... 224
1 What can magnets do? ... 228
2 How can we make magnets? ... 236
3 How does a compass show directions? ... 242
4 How do we explain magnetism? ... 251

Unit 8 How are all living things alike? ... 260
1 What can all living things do? ... 263
2 What are all living things made of? ... 270
3 What materials are in all living things? ... 277
4 How are living things different from non-living things? ... 283

Unit 9 Why do you eat different kinds of food? ... 288
1 Why do you need food? ... 291
2 What kinds of food do you need? ... 298
3 How can you choose the foods that you need? ... 313

Unit 10 How do living things depend on each other? ... 326
1 How do green plants make food? ... 330
2 How do plants and animals live together? ... 345
3 How do living things keep a balance of numbers? ... 358

Science words ... 368

Index ... 374

Acknowledgments ... 383

How do scientists think and work?

Over 100 years ago, Sir Humphry Davy, a great English scientist, worked in this laboratory. He had as a helper, young Michael Faraday, who later became a great scientist, too. Although they did not have much to work with, they made many important discoveries.

UNIT 1

Today scientists work in many different kinds of laboratories. Each kind of scientist has special instruments and materials to help him solve his problems. In this unit you will find out more about the way in which scientists work and the instruments they use.

LOOKING AHEAD TO UNIT I

When you think of a scientist at work, you probably imagine him in a modern laboratory surrounded with test tubes, delicate measuring instruments, and bottles of strange materials. Perhaps he is putting these materials together or taking them apart. Or maybe you imagine him bent over a microscope, carefully examining things too small to be seen with his naked eyes. If you watched a scientist at work today, those are actually some of the things you might see.

Now suppose you could watch a scientist at work 2000 years ago. How different the picture would be! You would not find him working with instruments in a science laboratory, because most of the instruments scientists now use were invented during the last few hundred years. Yet that would not be the most important difference you would notice. In those days, wise men were studying the world around them and thinking about what they saw. But they did not always think and work as scientists think and work today. They did not have all the modern scientific ways of discovering the truth about the things they saw.

Before you learn how modern scientists think and work, let us see how a scientist of long ago tried to discover the true facts about the world. About 2300 years ago, there lived in Greece a famous thinker named Aristotle (ar′is tot′əl). He noticed that a light object, such as a feather, falls slowly to the ground, while a heavy object, such as a stone, falls much faster. He thought this over and then decided that heavy things always fall faster than light things.

Perhaps you might think that Aristotle would have done some experiments to find out whether his idea was really true. But in those days people did not do experiments to test their ideas. When they saw something happen, they thought about it and then decided why it happened. Once Aristotle had made up his mind that heavy objects fall faster than light objects, he taught it as a truth to his students. And because he was Aristotle, the famous thinker, no one doubted his idea for over 1900 years.

Then, about 350 years ago, an Italian scientist named Galileo (gal′i lē′ō) began to wonder whether heavy things actually fall faster than light things. He did not believe something just

Scientists of long ago solved problems by thinking and talking about them.

because he had heard or read or thought about it. He was a different kind of thinker from Aristotle. Until Galileo had tested an idea, he was not sure that it was true. So he decided to do an experiment to find out whether heavy objects fall faster than light objects. According to one story, this is what he did.

In the city of Pisa (pē′zə), where Galileo lived, there is a leaning tower about 180 feet high. From the top of the tower he dropped a small ball and a large ball at exactly the same time. They both seemed to fall at the same speed and hit the ground together. But Galileo was not yet sure that he had discovered the truth. He tried the experiment again and again, using other objects of different sizes and materials. In every experiment he got the same result. At last he decided that he had found the truth about falling objects. Heavy things and light things both fall at the same speed if there is no air to hinder them.

When Galileo told people what he had discovered, no one would believe him. They laughed at him for saying that he had disproved an idea of the great Aristotle. Finally, he persuaded a few men to come and see the experiment for themselves. Even then, they refused to believe what they saw with their own eyes. But Galileo was not discouraged. He kept on doing experiments to test the truth of other old ideas.

Today we praise Galileo and call him the father of modern science. From him we learned to think and work scientifically. He studied things carefully and described what he saw as accurately as he could. He did not just think up a reason for what he saw and then say his reason was true. Instead, he experimented to get the facts that would prove or disprove his ideas. He refused to believe that something was true until it had been tested and proved to be true.

Now let us see how modern scientists think and work. What is a problem in science? Where do scientists find problems? How do they go about the job of solving problems? How do scientific instruments help scientists make discoveries about our world?

1 What kinds of problems do scientists solve?

WHAT IS A PROBLEM IN SCIENCE? You have worked many arithmetic problems, and you know what they are. An arithmetic problem gives you some facts and asks you a question about them. You are to find the answer to the question. To do that, you must first choose the right way to solve the problem. Then you do the work and check your answer to see whether it is correct.

What kinds of problems do you think had to be solved when this huge mirror was moved from New York State to California?

There are other kinds of problems besides arithmetic problems. You have met and solved several of them already today. Perhaps when you started to school, you saw clouds piling up in the sky. Then you probably asked yourself a question like this, "Shall I wear my raincoat, carry an umbrella, or take a chance that it won't rain?" That was a problem because you did not know what to do. There were three different things that you could do, and you wanted to choose the right one.

Every day we all meet many different problems that we must solve. All of these problems are alike in one way. We are trying to find the answer to some question. We are puzzled about something. We have to do something, but we do not know what is the best thing to do. Or we want to know something, but we are not sure how to find out.

A scientist is not a magician with a wand and a bag of tricks. He is just a human being like yourself. He has the same everyday problems to solve that you have. But besides these problems of his own, he wants to solve problems about what he sees in the world around him. He is always looking for facts that will answer his questions about our world. These questions about the world we live in are problems in science.

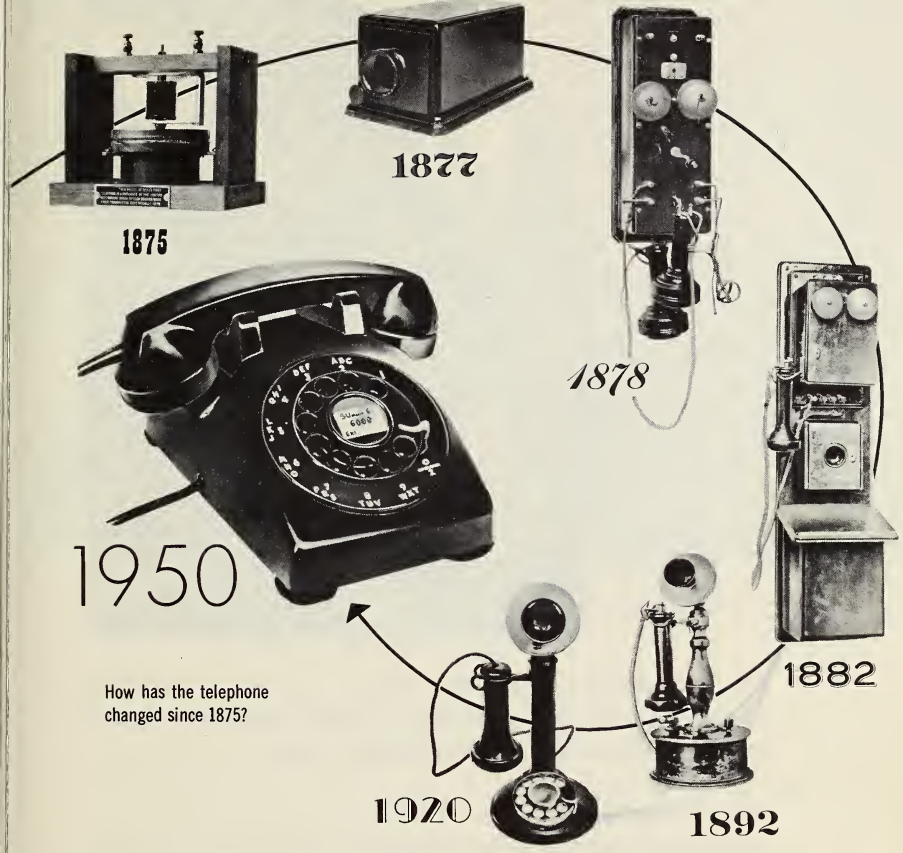
Many people do not understand what science is. When they think of science, they usually think of the inventions that science has made possible. Of course, these inventions are important to us all. Because of them, our lives are easier and safer. But before we can have these inventions, someone must find out the facts. An invention only puts into use the facts that scientists have discovered.

For a long time people have wanted faster methods of communication. But until the telegraph was invented a little over 100 years ago, there was really no fast way of sending messages. If you studied science before, you know that every telegraph set must have an electromagnet. You can easily make an electromagnet yourself. Wind some covered copper wire around an iron nail and connect the ends of the wire to a dry cell. The nail becomes a magnet, and it will pick up iron nails. When you disconnect the wire from the dry cell, the nail is no longer a magnet.

These facts seem very simple to us now, but scientists did not discover them until about 1820. At that time no one knew that an electromagnet could be put to any practical use. Scientists were just trying to find out all the facts they could about electricity and magnetism. The telegraph was not invented until fifteen years later. After the telegraph came the telephone, radio, and television. But before those inventions could be made, scientists had to discover many other facts about electricity and magnetism.

Some scientists spend their lives just searching for facts. We call them *research* scientists. They are mainly interested in discovering all they can about the conditions, materials, forces, and living things in our world. They want to find out what things are and also how and why these things behave as they do. These scientists are not much interested in what practical use can be made of their discoveries. At the time when the discoveries are made, they often have no use whatever. For about fifty years research scientists have been trying to learn more about powerful rays called *cosmic* rays. These scientists do not know or even care whether the facts they discover can be put into practical use. But someday other scientists may find ways to use the discoveries.

Many scientists are working on practical problems. As new facts are discovered, these scientists improve inventions we use



How has the telephone changed since 1875?

every day. The telephone was invented only about seventy-five years ago, yet it has been changed so much that you would hardly recognize the first one. But the need for better methods of communication is only one of the problems practical scientists are trying to solve. A few of the many other practical problems are how to make airplanes fly faster and higher, how to grow more food, how to get rid of insect pests, how to prevent diseases, and how to make better materials.

Science is really a way of searching for facts that will give us a better understanding of our world. The most important facts are usually discovered by research scientists, but sometimes they are discovered by practical scientists, too. To have progress in science,

An astronomer studies the sky with a telescope.

we need both kinds of scientists. They see problems where other people do not. As these problems are solved, new problems come up. Scientists never run out of problems to solve.

SELF-TESTING EXERCISES

1 State two important differences between modern science and the science of long ago.
2 Why was Galileo's idea about falling objects more likely to be correct than Aristotle's idea?
3 Explain what a problem is. Then give three everyday problems that you must solve.
4 Why do we need both research scientists and practical scientists?
5 What do we mean by science?

WHERE DO SCIENTISTS FIND PROBLEMS? You can probably give an answer to that question right now. Scientists find problems everywhere in our world. Of course, that is true. But our world is a very big place, and there are many different kinds of

Sending up balloons is one way in which meteorologists can find out about the weather. The geologist in the right-hand picture is making a map.

problems to solve. You can understand more easily what the problems are like if the same kinds of problems are grouped together.

There is a big group of problems about the earth. Scientists called *geologists* (ji ol′ə jists) are solving problems about the earth's surface and what is under it. What is the earth like? How did the earth come to be as it is today? Why are there mountains, plains, and oceans in different parts of the earth? What makes earthquakes and volcanoes?

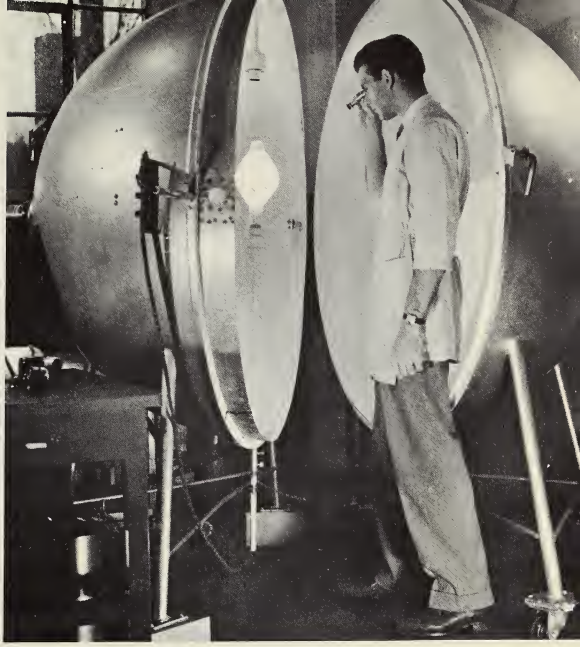
Meteorologists (mē′ti ər ol′ə jists) are studying changes in the weather on the earth. What makes the weather change? Why do different parts of the earth have different climates? *Astronomers* (əs tron′ə mərz) are trying to learn about the earth's relation to the sun, moon, stars, and other heavenly bodies. What effect do the sun and the moon have on the earth? Why do we have days and nights? What makes the seasons change? Those are only a few of the hundreds of problems about the earth. Though many of the problems have already been solved, many more important problems are still unsolved.

Another big group of science problems has to do with materials. All of the materials we use come from the earth. Some of them are used just as they are found. Others are made by putting materials together or taking them apart. The scientists who work on problems about materials are called *chemists* (kem'ists). These scientists find out what materials are made of, and they also discover new materials. They have learned how to separate iron, aluminum, lead, copper, and other metals from ores. They know how to make many useful materials from coal, oil, and wood. Yet there are still plenty of problems for chemists to solve.

All around us, things are moving—air, water, automobiles, trains, and airplanes. You yourself or parts of your body are always moving. But nothing moves unless it has been pulled or pushed by a force. And without energy, there would be no force. If you studied science before, you know what energy is. Scientists say that energy is the ability to do work. The energy stored in your muscles makes it possible to move your body. For a long time the energy of muscles was the only form of energy that people knew how to use. They did all their work with their own muscles or the muscles of animals.

Hundreds of years went by before people learned how to use the energy of moving air and moving water to run machines. Many problems about force and energy had to be solved. The scientists who study this group of problems are called *physicists* (fiz'i sists). Little by little, these scientists discovered the facts about other forms of energy. They found out how to do work with the energy stored in fuels. Now we have machines run by the force of steam and exploding gas. We also have many devices that use the energy of electric current.

Physicists are still solving problems about force and energy. For nearly fifty years these scientists have known that huge amounts of energy were locked up in materials, but they did not know how to set this energy free. After trying many experiments, they found an answer to the problem about ten years ago. Today we have *atomic* (ə tom'ik) energy. So far, this new form of energy has been used mainly for destruction. Scientists are now trying to discover how to use atomic energy to run our machines.



This physicist is testing the color of the light from a new kind of mercury-vapor lamp.

The last big group of problems has to do with us and all other living things—animals and plants. The scientists who study living things are called *biologists* (bī ol′ə jists). These scientists discover how living things are put together, what they are made of, and what they do to keep alive. Biologists look for ways to improve the living things we have and for ways to take better care of the plants and animals we need. They also look for ways in which we can take better care of ourselves. Many discoveries about food, disease, and growth have already been made. Because of those discoveries, you now have a chance to live forty years longer than people who were born 100 years ago.

SELF-TESTING EXERCISES

1 List the four big groups of problems that scientists try to solve. Then after each group tell what the scientists working on these problems are called.

2 For each group of problems you listed in Exercise 1 give at least three problems that scientists have solved or are trying to solve. Write the problems as questions.

Some biologists study plant diseases and tell farmers how they can keep their crops from getting these diseases.

PROBLEMS TO SOLVE

1 Look through newspapers and magazines to find articles about science. What kinds of science problems are mentioned? Which problems have been solved or partly solved?
2 Do you think that there will ever be a time when we will not need scientists? Give reasons for your answer.
3 What problems in your community could scientists help solve?
4 Some people think that every scientist should spend his time inventing useful things instead of just searching for facts. Do you agree with that idea? Explain your answer.
5 Give an example of your own to show that a new discovery or invention often brings up new problems to solve.

2 How do scientists solve problems?

HOW DOES A GOOD THINKER SOLVE A PROBLEM? You have been learning about the kinds of problems that scientists solve. Now you are going to find out how scientists solve problems. You need to know how a scientist thinks and works, because you are going to solve some science problems yourself. You will want to get the best answers you can. So let us first take a simple problem and see how you could solve it by good thinking.

Other biologists take care of animals. These animal doctors, or veterinarians, are making a test to see whether the turkey has a disease.

Your new model airplane comes down in a tree while you are flying it. Your problem is how to get it out of the tree. You quickly think of several ways that you might solve the problem. But before you try anything, you think over these different ways to decide which way is the best. You can see that the tree is too big to shake. You are afraid that throwing sticks at the airplane might break it. So you give up these two ways without even trying them.

There is a ladder at home, and you know just about how tall the ladder is. You can see that the airplane is too high to reach even if you stand on the top step of the ladder. You give up that idea, too. You think of climbing the tree. But the airplane is out near the end of a small limb, and you decide that the limb will not hold you up. You see a big limb just above the one where the airplane is. If you hold on to the upper limb, maybe you can work your way out almost to the airplane. Then perhaps you can shake the small limb enough to jar the airplane loose. This seems to be the best plan of all. So you decide to try it. You do try it, and it works. At last you have solved your problem.

Perhaps you are wondering why this is an example of good thinking. Let us go through the steps you used in solving the problem. First of all, you knew exactly what you were trying to do. You could see what the problem was. Of course, in this simple

example the problem was easy to see. But many times it is very hard to know what you are trying to find out. Next you thought of ways to solve the problem. A poor thinker often fails at this point. He takes the first plan that he thinks of and tries it. If this plan does not work, he tries the next one that he thinks of and so on. At last he either solves the problem, or he runs out of ideas and gives up. He wastes much time and may do something foolish or dangerous.

You were a good thinker, and you did not work that way. You thought of several ways to solve the problem, but you did not try every plan as you happened to think of it. Instead, you studied each plan carefully to see whether it would work. You decided that some of the plans were not good. So you did not even try them. Then you chose a plan that you thought would work. You tried it to find out whether it would actually solve the problem. In other words, you did an experiment to test your idea. Careful scientists do many experiments to test their ideas before they are sure that the ideas are true.

SELF-TESTING EXERCISES

1 What was the problem about the model airplane?
2 List the steps that a good thinker would use to solve the problem of the model airplane. Explain why each step shows good thinking.
3 Why is it better to think a problem through before acting than to try each thing that you think of?

HOW IS A PROBLEM IN SCIENCE SOLVED? There is nothing mysterious about the way in which scientists think and work. A scientific thinker is just a good thinker. When a scientist has a problem to solve, he follows the same steps that any good thinker would use. Let us take a problem in science and see how scientists would go about the job of solving it.

Farmers used to raise corn year after year in one field. In another field they would grow wheat year after year. They noticed that the crops were getting poorer each year, but they did not know why. They planted the same kinds of seeds in the same way every year. Yet the plants got smaller and smaller, and there was less grain to harvest. When the farmers used land

1 How the crop decreased

First year Second year Third year

2 How the corn plants looked

First year Third year

3 Testing the soil

Study the pictures on this page and the next.

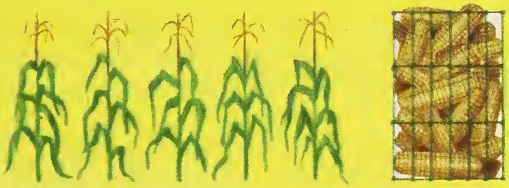
where no crops had been raised before, the plants would grow very well for a while. Then after a few years the crops would again begin to fail. The farmers were puzzled. This was a problem for scientists to solve.

The scientists thought of all the things that might keep the plants from growing well. Poor crops might be caused by several years of bad weather. But the records of the Weather Bureau showed that the weather had been fairly good during the past few years. So the weather was probably not the cause of poor crops. The scientists knew that growing plants take certain minerals from the soil. They learned this fact by finding out what materials plants are made of. So the scientists thought, "Perhaps the crops have used up the minerals in the soil, and that is why the plants won't grow well." This seemed to be a good idea, but of course it had not been proved. How could it be proved?

The best way to prove it was to do some experiments. First of all, the scientists decided to test the soil where the crops had been grown. If the crops took minerals from the soil, there would be a

4 Spreading fertilizer on the field

5 Corn crop after fertilizing the soil



What signs made scientists think that the soil lacked minerals? How did they find out whether this was the cause of poor crops?

difference between the soil that had been used and the soil that had not been used to grow plants. The scientists took a sample of each soil and tested the sample to find out what minerals were in it. They discovered that there was a difference between the two soils. The unused soil had more of the minerals that plants need than the used soil had. The scientists thought that they were on the right track. But they could not really be sure. They still had not proved that the lack of minerals in the soil was the cause of poor crops.

Before the scientists could be sure that this was the real cause of poor crops, they had to do another experiment. The plants should grow better if the minerals were put back into the soil. This was good thinking. But the scientists could not be sure that it was right just because it seemed to be a good idea. They had to test the idea by doing an experiment. So they added the minerals to the soil, planted the seeds, and then waited for the harvest. The result was just what they thought it would be. The plants grew well and produced a good crop for the first time in years.

But still the scientists were not ready to say that their idea was right. They tried the experiment over again several times. Each time they got the same result. At last they were sure that they had found the real cause of poor crops. The crops had used up most of the minerals in the soil, and so the plants could no longer grow well. But if the minerals were put back into the soil, the plants would grow better and produce good crops. We use this discovery whenever we put fertilizer on soil to make it richer.

Now you have seen how a problem in science is solved. Scientists use much the same way to solve their problems as any good thinker uses to solve his problems. This way in which scientists think and work is called the scientific method. It is a very useful way to solve many different problems. Here are the steps that a scientist usually follows in solving a problem.

1 A scientist gets clearly in mind the problem that he wants to solve. He sees just what it is that he is trying to do or explain or prove or disprove.
2 He thinks of as many ways as he can to solve his problem or to explain the facts that he has found.
3 He chooses the solution or explanation that seems to be correct.
4 He plans and does an experiment to see whether the solution or explanation is correct.
5 If the experiment seems to show that the solution or explanation is correct, he makes sure that it is correct by doing other experiments to test it.

The fifth and last step in the scientific method is very important. Careful scientists always *verify* discoveries. In other words, scientists prove discoveries to be true by testing them in many different ways. When a scientist announces a discovery, he usually tells how he did his experiments and how he verified the results. He does just what you do when someone says, "Well, how do you know that is true?" Other scientists repeat his experiments and also try new ones to test his results. They want to make sure that the discovery is true before they believe it. Scientists do not accept a new discovery until it has been carefully verified.

SELF-TESTING EXERCISES

1 List the five steps that scientists follow in solving a problem. Then show how each step was used to solve the problem of the crops that did not grow well.
2 Why do scientists do experiments?
3 What does it mean to verify something? Show that you understand the meaning by giving an example of your own.
4 Why are the discoveries announced by careful scientists likely to be true?

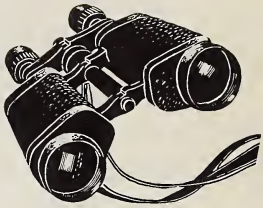
PROBLEMS TO SOLVE

1 Read again the story of Aristotle and Galileo, pages 6-8. Which steps in the scientific method did Aristotle use? Which ones did he not use? How did Galileo use all the steps to solve the problem of falling objects?
2 Some people believe that handling toads will cause warts. How would you prove whether or not this belief is true?
3 When John tried to fly his kite, he found that it would not go up in the air. How could he go about solving the problem of why it would not fly?
4 Mother baked a cake, but it did not turn out well. What problem would she want to solve? How could she try to solve it?
5 State some problem of your own and tell how you could use the scientific method to solve it. Be sure to mention each step that you would follow in solving the problem.

3

How do scientific instruments help scientists make discoveries?

When you read about some of the things that people believed a few hundred years ago, you probably wonder how anyone could have believed such things. You know that the earth is shaped like a ball and that it moves around the sun. Yet there was a time when even the wisest men believed that the earth was flat. They also thought that the sun, moon, stars, and other heavenly bodies moved around the earth. You probably know that frogs



At a football game it is often hard to see how a player catches the ball and gets away from the other players who are tackling him.

grow from tiny eggs laid by a mother frog. But not so long ago people believed that frogs grew from mud at the bottom of streams and ponds. Two thousand years ago the wisest men thought that all the different things on the earth were made from only four materials—air, water, soil, and fire.

We may laugh at the queer ideas people once had about our world. But we should remember that scientists of those days did not have the scientific instruments we use today. With these delicate instruments scientists can see and hear and weigh and measure as they could not do before. Of course, the most important difference between modern science and the science of long ago is the way in which modern scientists think and work. But these scientists depend on scientific instruments to get accurate results. Without scientific instruments, many discoveries could never have been made at all. Let us see what some of the most useful instruments are.

About 350 years ago, a Dutch eyeglass maker named Lippershey (lip′ərs hī) accidentally invented the telescope. When he looked through a pair of glass lenses, things that were far away seemed to be nearby. To him, his invention was just an interesting toy. But

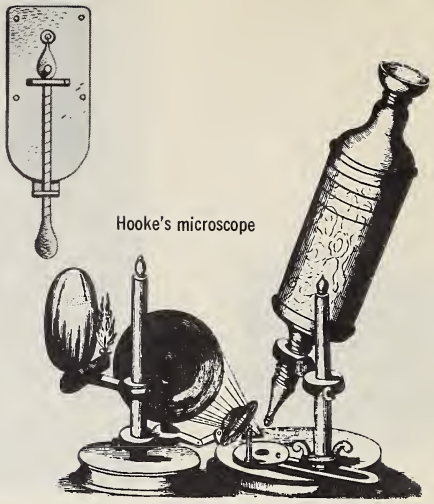
But if you have a pair of field glasses, or binoculars, the player appears to be so close that you can see just what he is doing.

Galileo heard about the telescope and made one for himself. Looking at the night sky through his telescope, he saw things that no human being had ever seen before. Galileo discovered four moons circling around the planet Jupiter. This discovery proved that not all of the heavenly bodies move around the earth. Soon afterwards other scientists showed that the earth and all the other planets actually move around the sun.

Since the telescope was invented, scientists have greatly improved it. Two of the largest telescopes are in California. The one on Mount Wilson is so powerful that through it you can see a light no bigger than a candle flame 5000 miles away. With your naked eyes you can see only about 5000 stars. This giant telescope brings 500,000 stars into view. An even larger telescope on Palomar Mountain is now in use. With this huge instrument scientists are now able to see twice as far as they can with the telescope on Mount Wilson.

Another very useful scientific instrument was invented about the same time as the telescope. For several hundred years people had used a magnifying glass to make small things look bigger. Then about 350 years ago, a Dutchman named Janssen (yän′sən)

Leeuwenhoek and his simple microscope



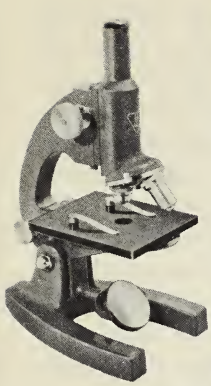
Hooke's microscope

Nearly 300 years ago, Robert Hooke used this compound microscope to look at all kinds of things He was the first to use a microscope to study thin slices of cork and other plant materials.

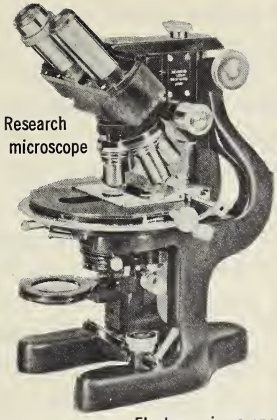
used two magnifying glasses instead of one and invented the compound microscope. For a long time the microscope was mostly a toy, though a few scientists used it to look at insects. Of course, the first microscopes were not well made. They did not show the very tiny things we can see with modern microscopes. Even so, it is hard to understand why almost 250 years went by before scientists realized how important the microscope was.

To your naked eyes, a glass of water may look perfectly clear and pure. But a microscope may show that the water is full of germs. These germs are much too tiny to be seen with your unaided eyes. Until about 300 years ago, no one had ever seen anything so small. Then another Dutchman named Van Leeuwenhoek (vän lā′vən hůk) looked at a drop of pond water through a simple microscope he had made.

Imagine his thrill when he found the water swarming with tiny living things! He thought that these living things were animals. Today we know that they were really tiny plants called bacteria (bak tēr′i ə). We also know that some kinds of bacteria are germs. But nearly 200 more years went by before scientists discovered that germs cause many diseases. Without a microscope,

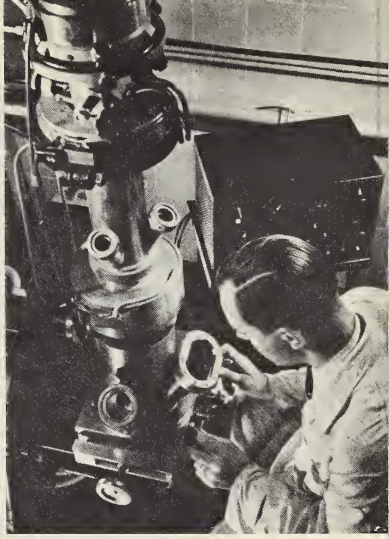


Student microscope



Research microscope

Electron microscope



The research microscope above is called a binocular microscope because it has two eyepieces, as a pair of binoculars has. As you can see, an electron microscope is much larger than other microscopes.

this discovery would never have been made. Today doctors and many other scientists depend on microscopes to help them solve their problems.

Until about ten years ago, the most powerful microscope that scientists could make magnified objects 2500 times. Then an entirely new kind of microscope was invented. It can be used to make things look 200,000 times larger. This new instrument is called the *electron* (i lek′tron) microscope. An ordinary microscope uses rays of light. But the electron microscope uses an invisible beam of electrons, which are particles of electricity. With the new microscope, biologists have at last seen the very tiny germs that cause influenza. Other important discoveries have also been made.

Scientists have solved many problems with another useful instrument. It is called the *analytical* (an′ə lit′i kəl) *balance*. This instrument is just a very delicate pair of scales for weighing things. Some of these balances can weigh the pencil marks you make when you write your name, and others are even more sensitive. Many of the important discoveries about materials were made by chemists using the analytical balance.

Another extremely sensitive instrument is the *spectroscope* (spek′trə skōp). Using a spectroscope, astronomers have discovered what materials the sun is made of. When you remember that the sun is 93 million miles from the earth, you can understand how sensitive this instrument must be. With a spectroscope a scientist can tell what a star is made of, how hot it is, and whether it is moving toward us or away from us. Most of what we know about the heavenly bodies was discovered with the spectroscope and the telescope. Chemists use the spectroscope to find out just what is in the materials they are studying.

With a spectroscope a material never known to exist before was discovered in the sun. This material was unknown on the earth. So the scientist who discovered the material named it helium (hē′li əm), which means sun element. Thirty years later, another scientist was using a spectroscope to examine a mineral

This scientist is studying some neon gas with a spectroscope.

Using an analytical balance takes much skill and patience.

that is common on the earth. He found helium in the mineral. Then large quantities of helium gas were discovered in a few places in the earth. Now helium is used to fill big balloons.

Every time you look at a thermometer to tell the temperature, you are using a scientific instrument. Our common thermometers are not very accurate. If they measure within a degree or two of the correct temperature, they are accurate enough for everyday use. But scientists need much more accurate and sensitive thermometers than the ones we use every day. Some of their thermometers can measure the heat from a group of candles several miles away. If one of the candles goes out, the thermometers will show a change in temperature. Astronomers use such thermometers to find the temperature of planets and stars.

When a doctor examines you, one of the first things he usually does is to take your temperature with a *clinical* (klin′i kəl)

In the light from this instrument, fresh eggs look scarlet and old eggs look purple.

These doctors are studying an X-ray photograph of a patient's chest.

thermometer. He uses many other scientific instruments in his daily work. You already know that a microscope is needed to study germs. A doctor uses an instrument called a *stethoscope* (steth′ə skōp) to listen to your heartbeat. The sounds that he hears with this instrument also tell him about the condition of your lungs. He can examine bones and other things inside your body with an X-ray machine. All these instruments help a doctor discover what is making you sick. When he finds out what the disease is, he can usually work out a way to fight it.

Now you can understand why scientific instruments are important. Without these instruments, scientists could not have made most of their greatest discoveries. And we would not know much more about our world today than people knew 2000 years ago. As you go on with your study of science, you will learn more about scientific instruments. You will also learn how scientists use these instruments to solve problems about the world we live in.

SELF-TESTING EXERCISES

1 Why can modern scientists discover more facts about our world than scientists of long ago could discover?
2 How does each of these instruments help scientists solve problems? Telescope, microscope, analytical balance, spectroscope, thermometer, stethoscope, X-ray machine.
3 Suppose a scientist writes a careful description of something he has observed. You look at the thing he has described, but it does not look like the same thing to you. Who is more likely to be correct, you or the scientist? Explain your answer.

PROBLEMS TO SOLVE

1 Name some instruments you have used to help you see, hear, weigh, and measure. Then tell how each one helped you.
2 Describe some instruments you have seen a doctor use. What did he find out with each instrument?
3 If you have ever had your eyes tested, tell what the doctor did to find out whether you needed glasses.
4 How do you think a scientist could use motion pictures to help him solve a problem?

SUMMARY EXERCISE

Write about one page to answer the question of this unit: How do scientists think and work? Be sure to mention all the important ideas you learned by studying the unit.

ADDITIONAL ACTIVITIES

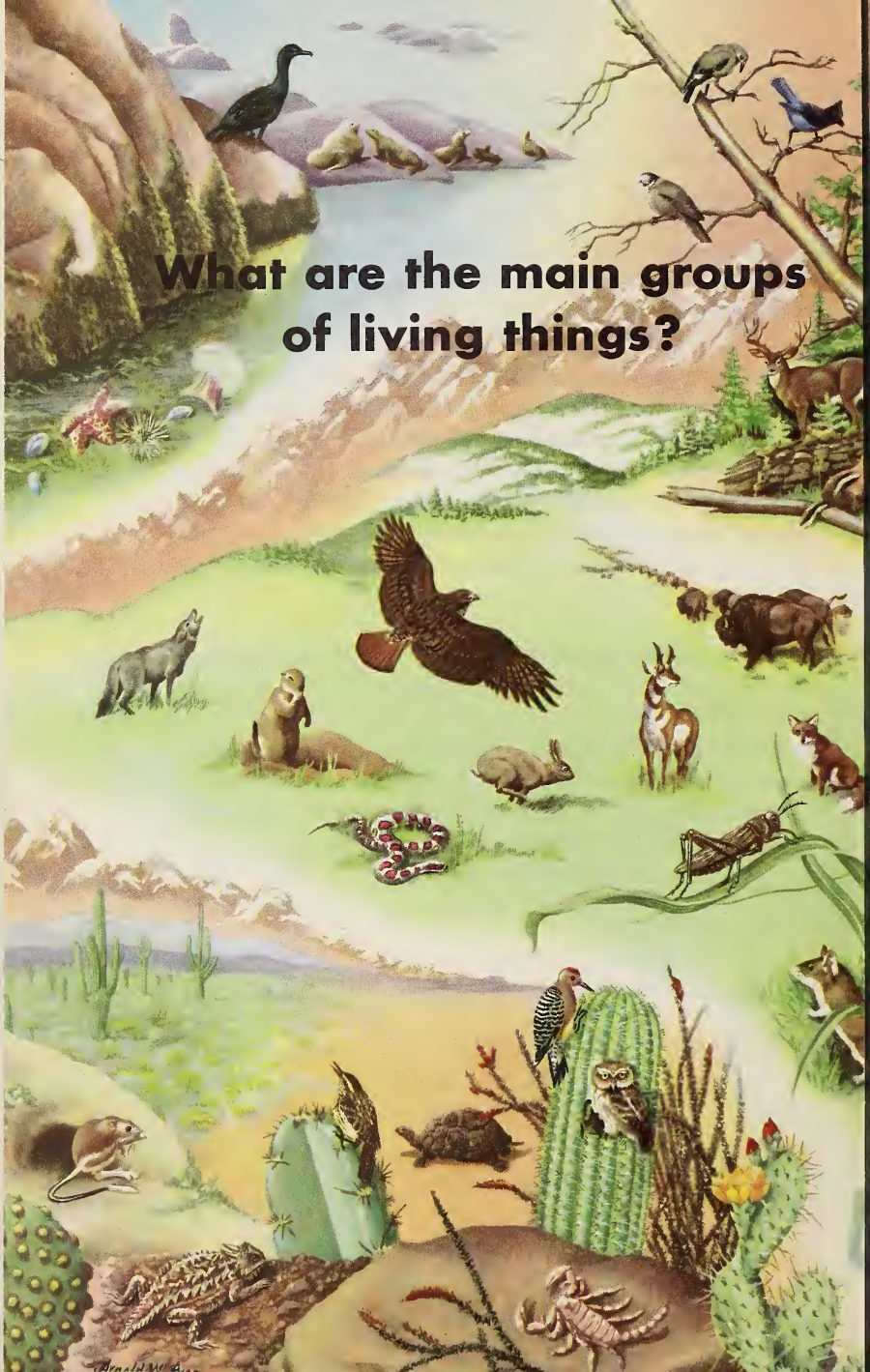
1 You will find many articles about science in newspapers and magazines. Keep a scrapbook of articles about new discoveries and inventions that scientists make.

2 Look at something very small with your naked eyes. Then examine it with a magnifying glass or a microscope. What can you see with the instrument that you could not see without it?

3 Usually when a scientist announces a discovery, reporters talk to other scientists to find out what they think about the discovery. After a discovery has been announced, watch the newspapers to see what other scientists say. If they accept the discovery as true, why do they do so? If they are not sure that it is true, what reasons do they give?

4 On a clear night look at the sky with your unaided eyes. Then look through a pair of field glasses or a telescope. What differences do you notice?

5 In reference books, read about the following topics: Galileo and the telescope; Leeuwenhoek and the microscope; the invention of the telegraph and the telephone; the uses of coal tar; the manufacture of aluminum and Portland cement; the invention of the steam engine and the gasoline engine.


What are the main groups
of living things?

UNIT 2

On a trip across our country,
you see forests and deserts, plains
and seashores, mountains and oceans.
You see different kinds of plants
and animals in each of these regions,
as the map and pictures show. What
way of grouping plants and animals
might a trip like this suggest?
In this unit you will learn how
scientists group plants and animals.
As you study the unit,
look at these pages again and find
plants and animals belonging to the
different groups.

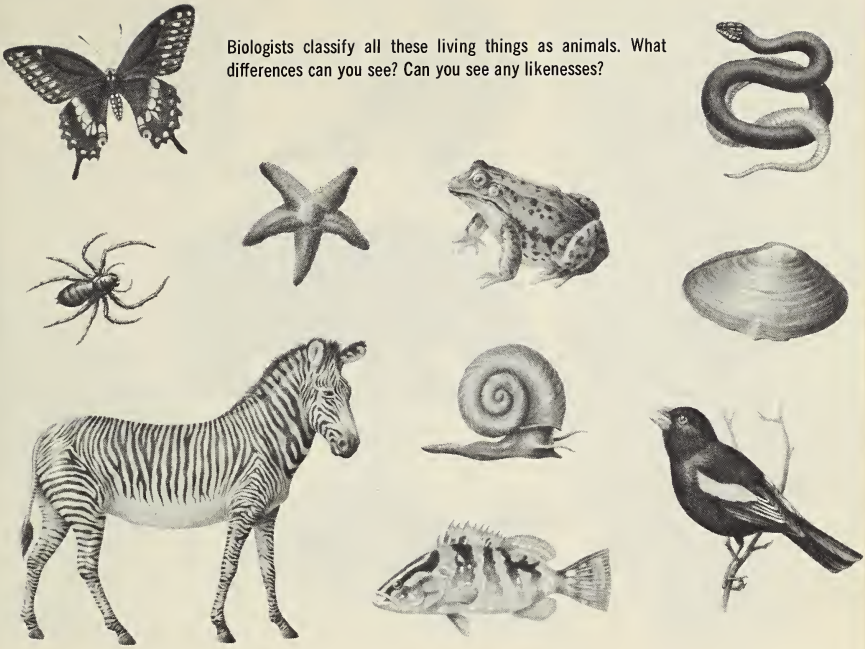
LOOKING AHEAD TO UNIT 2

If you see a strange animal or plant, you probably ask, "What is it?" Sometimes that is a hard question to answer. Scientists have discovered and named more than 850,000 different kinds of animals and over 340,000 different kinds of plants. And those are not all the kinds of living things, because new kinds are discovered every year. If you spent your whole life studying animals and plants, you could never learn to tell all the different kinds apart. Not even an expert biologist knows all the kinds of living things.

However, scientists have worked out a way that will help you study living things. They *classify,* or put together in a group, living things whose bodies are alike in some ways. You already know that living things can be separated into two big groups: animals and plants. Each of those groups can then be divided into other groups. You can easily learn how to tell the main groups of animals or plants apart. When you know what the main groups are like, you can often decide in which group a strange animal or plant belongs.

All kinds of birds are put together in one group of animals, because all birds have bodies that are alike in some ways. For one thing, every bird has feathers. No other kind of animal has them. So feathers are the most outstanding characteristic of birds. A characteristic describes something or tells what it is like. Besides feathers, birds have other characteristics such as two legs and two wings. Whenever you see an animal with those three characteristics, you know at once that it must be a bird.

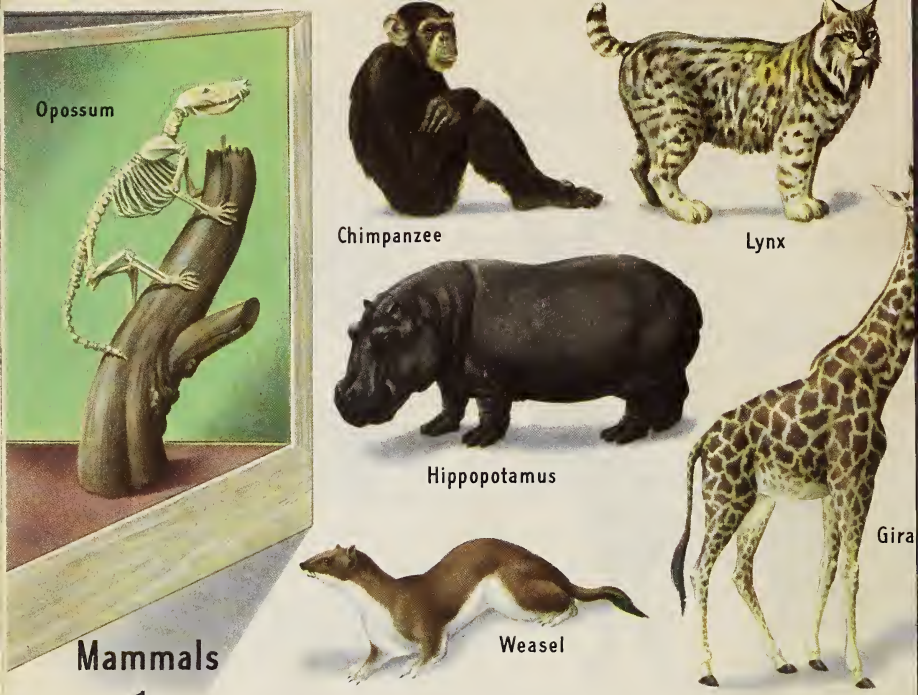
As you study the main groups of animals and plants, you will learn their most important characteristics. But first you should understand how we use these characteristics to classify living things. Look carefully at the picture on the next page. All the living things shown there are animals. Each animal has some characteristics that the others do not have. The body of each animal is made up of different parts put together in a different way. In other words, each animal has different characteristics of structure. It is easy to see that these animals are different, but it is not so easy to see how some of them are alike.



Biologists classify all these living things as animals. What differences can you see? Can you see any likenesses?

Can you divide the animals in the picture into two groups according to their structure? Probably not. But a biologist can do this because he knows how the bodies of the animals are put together. He examines the whole structure of a living thing, inside and outside of its body. He would put the zebra, the bird, the snake, the frog, and the fish in one group. Each one has a characteristic of structure that all the others have: a backbone. Then he would put the butterfly, the spider, the snail, the clam, and the starfish in the other group. Each one has a characteristic of structure that all the others have: no backbone.

Plants as well as animals can be classified according to their structure. Each group of animals or plants has its own characteristics, and no other group has exactly the same ones. When you learn the characteristics of a group, you know that each living thing in the group has those characteristics. Or if you know in which group a living thing belongs, then you can tell at once some characteristics of its structure.



Mammals

1 What groups of animals have backbones?

Your backbone, or spine, helps hold together the other bones of the skeleton inside your body. Many separate bones make up your backbone. Each bone is called a *vertebra* (vėr′ti brə). Each vertebra has a hole through it. Your main nerve cord, or spinal cord, runs inside your backbone through the holes in the *vertebrae* (vėr′ti brē). A backbone, a skeleton inside your body, and a spinal cord are three characteristics of your structure.

You have seen how characteristics of structure help us classify living things. All animals with backbones can be put in one big group. We call the animals in that group *vertebrate* (vėr′ti brāt) animals, or vertebrates. Every vertebrate animal has a skeleton inside its body and a spinal cord inside its backbone. There is another characteristic of structure that all vertebrates have. The openings through which they breathe are connected with the front end of the food tube near the mouth.

Mallard duck

American bald eagle

Nuthatch

Great blue heron

Ring-necked pheasant

Penguin

Cardinal

Birds

Common water snake

Turtle

Chameleon

Collared lizard

Alligator

Reptiles

Scientists have discovered and named about 40,000 different kinds of vertebrates. But this big group of animals with backbones can be divided into five main groups: mammals, birds, reptiles, amphibians, and fish. Each group of vertebrates has some characteristics of structure that the others do not have. However, as you study the five groups, remember that the animals in every group have the characteristics of vertebrates as well as the characteristics of their own group.

Some of the mammals that you know are dogs, cats, horses, cows, sheep, pigs, rabbits, squirrels, rats, mice, deer, elephants, camels, lions, tigers, wolves, and bears. Others are bats, whales, seals, and kangaroos. All together, there are about 4000 kinds of mammals. Yet they all have some characteristics of structure that are alike: (1) Mammals have hair or fur all over their bodies or on some parts of their bodies. (2) Female mammals have milk glands from which they feed milk to their young. (3) Mammals have a large sheet of muscles, called a *diaphragm* (dī′ə fram), that divides the inside of their bodies into two parts. One part is the chest, or thorax, which contains the heart and lungs. The other part is the abdomen, which contains the stomach and intestines. Only mammals have these three characteristics of structure.

Mammals are warm-blooded, too. Their bodies stay very near the same temperature all the time. They breathe air with lungs. All but two kinds of mammals give birth to living young instead of laying eggs as most other animals do. The young are carried inside the mother's body for a time before they are born. Other vertebrates have some of these characteristics, but none has them all.

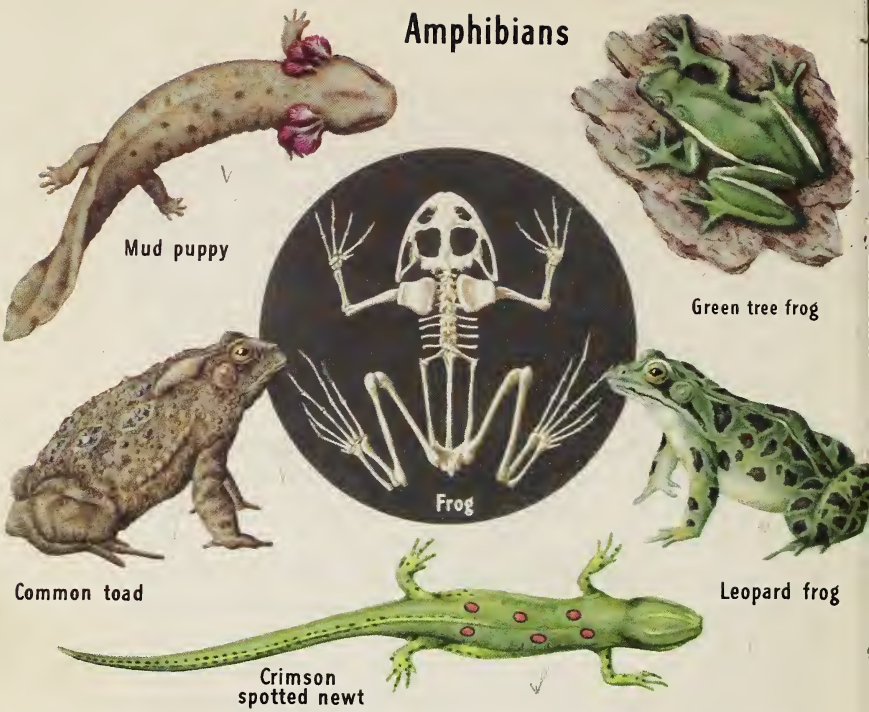
Whales and elephants are mammals. So you can see that the largest animals in our world are mammals. Some whales are 100 feet long and weigh nearly 150 tons. The smallest mammal is a mouselike animal called a shrew. It is about 2 inches long. Bats are the only mammals that have wings and can fly. Whales, porpoises, and dolphins spend their entire lives in water. They need to come to the surface only to breathe. Monkeys and squirrels spend most of their time in trees. Moles burrow in the ground. All these different animals are mammals because they have the characteristics of structure that only mammals have.

Scientists have discovered and named about 14,000 kinds of birds. But anyone can tell a bird when he sees one. All birds have feathers, and only birds have them. Except for bats, birds are the only vertebrates that have wings. However, a bat has leathery wings instead of feathers. Birds have two legs and horny bills or beaks. Like mammals, birds are warm-blooded. Their body temperature may be as high as 100° or even 110° Fahrenheit (far′ ən hīt). (Fahrenheit refers to the kind of thermometer that we ordinarily use. Its abbreviation is F.) Birds also breathe air with lungs. They lay eggs that have brittle shells, and their young hatch from the eggs.

The largest birds are the ostriches, which may be 8 feet tall and weigh 300 pounds. These big birds cannot fly, but they can run faster than a horse. The smallest birds are the hummingbirds, which are not much bigger than your thumb. Penguins cannot fly, and they are really at home only in water. However, the birds that can fly are well equipped for flying. They have light, hollow bones and powerful flying muscles. Some of these birds migrate as the seasons change. In the spring, they fly north. When autumn comes, they fly south. Some of them fly as far as 11,000 miles each way every year.

When you speak of a reptile, you probably mean a snake. About half of the 4000 kinds of reptiles are snakes. The others are turtles, tortoises, alligators, crocodiles, and lizards. Reptiles are covered with scales or horny plates that develop from their skin. Those with legs have claws on their toes. Unlike mammals and birds, reptiles are cold-blooded. The temperature of their bodies does not stay about the same all the time. Instead, it goes up or down as the temperature of their surroundings changes. Where the winters are cold, reptiles that live on land become inactive. They burrow into the ground and hibernate, or sleep there all winter. When spring comes, they become active again.

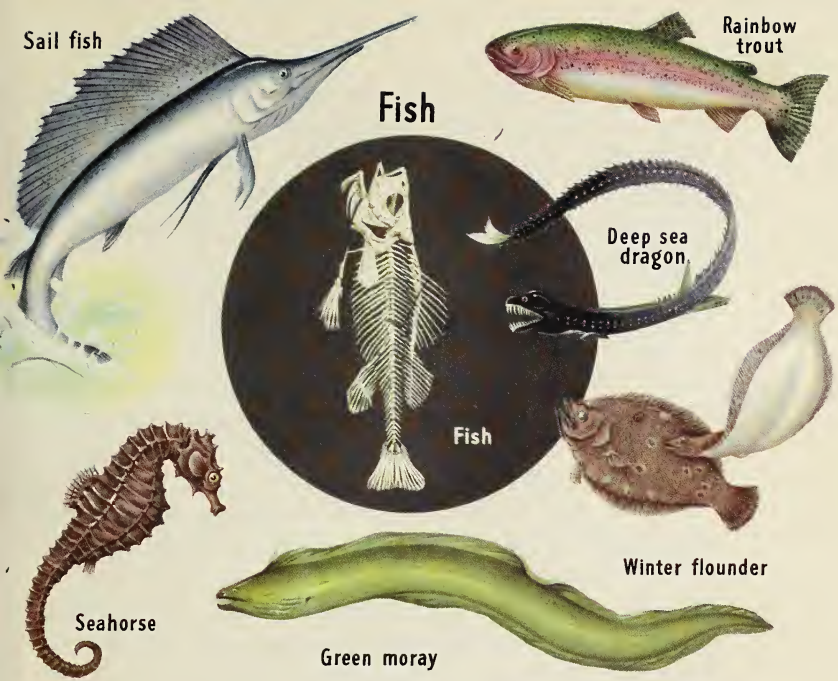
Like mammals or birds, reptiles breathe air with lungs. Those that live in water must come to the surface to breathe. Most reptiles lay eggs with tough, leathery shells. The females lay their eggs in the ground and cover them with sand, soil, or decaying plant materials. Then they go away and leave the eggs. When the



young hatch from the eggs, they must take care of themselves. Some snakes, such as the garter snake, keep their eggs in their bodies until the young are well developed. Then the young are born alive.

Millions of years ago, reptiles called dinosaurs (dī′ nə sôrz) ruled the earth. Some were almost 90 feet long and weighed about 40 tons. Today the largest reptiles are snakes called pythons, which sometimes grow to be over 30 feet long. Lizards about 12 feet long live on an island in the Pacific Ocean. Some land turtles, or tortoises, weigh 500 pounds. Sea turtles may weigh as much as 1500 pounds. However, most reptiles are much smaller.

Frogs, toads, and salamanders belong in the group of amphibians, which includes about 2000 kinds of vertebrates. Though salamanders are shaped somewhat like lizards, they are really very different animals. Unlike reptiles, amphibians are never covered with scales or horny plates. Frogs and toads have a rough skin, while salamanders have a smooth skin. Amphibians never have



claws as some reptiles do. But like reptiles, amphibians are cold-blooded. Where the winters are cold, they become inactive and hibernate.

The most unusual characteristic of amphibians gives them their name. Amphibian means having two ways of living. If you have ever watched tadpoles develop, you can understand why it is a good name for the animals in this group. Most amphibians lay their eggs in water. Tadpoles that look and act like small fish soon hatch from the eggs. The young animals have long tails and breathe with gills. The gills are delicate, fringelike parts that can take air from the water. After a while the tadpoles lose their gills and develop lungs. They also grow legs. Then they can come out of the water and live on land. (If the tadpoles are to be frogs or toads rather than salamanders, they lose their tails, too.) Most amphibians have these two ways of living. First they breathe with gills, and then they breathe with lungs. A few kinds do not develop in water, and a few others stay in water and keep their gills.

The largest amphibians are giant salamanders almost 6 feet long. The smallest ones are tiny tree frogs less than 2 inches long. Amphibians are usually timid, harmless creatures that do not scratch or bite. But hellbenders and tiger salamanders look fierce. Fishermen sometimes catch hellbenders and mud puppies on their hooks.

There are about 14,000 kinds of fish, and all of them live in water. The streamlined bodies of most fish are covered with scales or bony plates. Most fish have a broad, flat tail that acts as a propeller to push them through the water. Fish never have legs, but they do have fins that help balance and guide them in the water. Four of the fins are usually arranged in two pairs like the limbs of other vertebrates.

Fish are cold-blooded. They breathe with gills that are much like the gills of young amphibians. But the gills of a fish are inside its body, and they are usually protected with gill covers. A fish takes in water through its mouth and makes the water flow out through openings just back of its head. As the water flows out through the openings, it must go past the gills. They take air from the water. Most kinds of fish lay eggs that develop in the water, but a few kinds give birth to living young.

The largest fish are sharks about 40 feet long. The smallest are tropical fish about 1 inch long. Some kinds of fish have such queer shapes that you would hardly think they are fish. Sea horses are one strange kind. Eels look like snakes. Sting rays and flounders are very flat and thin. Fish with queer shapes live in the dark depths of the ocean. Some of them carry lanterns that light up the darkness. Flying fish cannot really fly, but they can glide through the air for short distances. Climbing fish come out of water and climb around in the branches of low trees, hunting for food. A few kinds of fish can breathe out of water, because they have something like a lung as well as gills.

SELF-TESTING EXERCISES

1 How are living things classified? Explain your answer.

2 **a** What do we mean by a vertebrate?

b State four characteristics of structure that all vertebrates have.

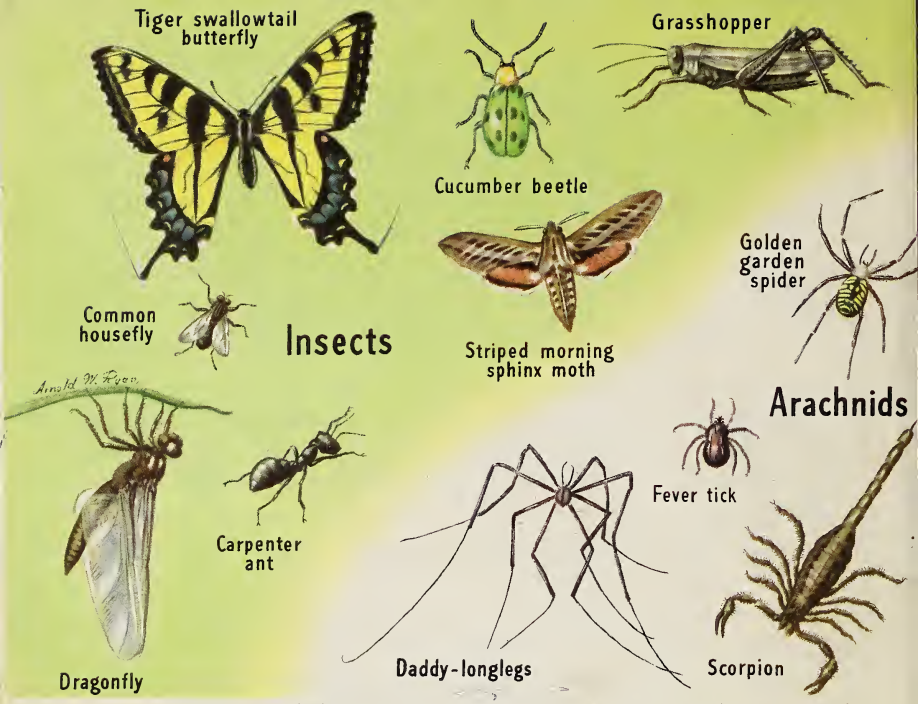
3 List the important characteristics of each group of vertebrates. Then mention at least two animals that belong in each group.
4 Name the groups of vertebrates that have these characteristics: **a** Hair or fur. **b** Two wings and two legs. **c** Lungs. **d** Skeleton inside the body. **e** Feathers. **f** Cold-blooded. **g** Backbone. **h** Diaphragm. **i** Warm-blooded. **j** Lay eggs. **k** Milk glands. **l** Fins. **m** Spinal cord. **n** Scales or hard plates. **o** Produce living young. **p** Gills.
5 Why is amphibian a good name for the animals in that group?

PROBLEMS TO SOLVE

1 Look at the picture on page 35. In what group does each vertebrate belong? Give reasons for your answers.
2 How do you think that scientists decided that a whale is not a fish and a bat is not a bird?
3 In what group of vertebrates do people belong? Explain your answer.
4 Do you think that it would be a good plan to classify animals according to where they live? Why?
5 Scientists know that an animal called the horned toad is really a reptile, not an amphibian. How do you think that they know this?
6 The animals in each group of vertebrates are alike in some ways, but they are also different from one another. Give some examples to show that this is true.
7 If you can, examine at least one animal in each group of vertebrates. Does it have all the characteristics of the group? What other characteristics does it have?

2 What groups of animals have no backbones?

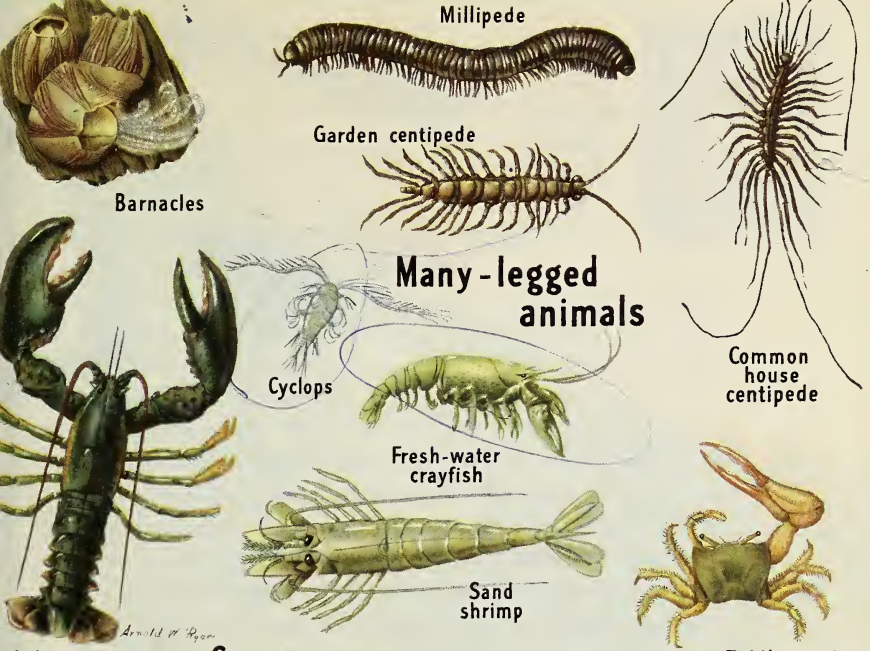
The large animals that you often see — your pets, farm animals, and the animals in zoos and circuses — are all vertebrates. So you probably think that most kinds of animals have backbones. However, that is not true. Scientists have discovered and named more than 850,000 kinds of animals, but only about 40,000 kinds are vertebrates. All the other kinds have no backbones. We call these animals without backbones *invertebrate* animals, or invertebrates. (In- means not.)



You probably do not notice many of the invertebrate animals, because they are usually small. Many of them are so tiny that they cannot be seen without a microscope. They often live in soil, water, or the bodies of other living things. Yet the huge group of invertebrates is important. From some kinds we get food and other materials that we use. Other kinds destroy the plants and animals that we need. And some others can cause disease.

WHAT GROUP OF ANIMALS HAS JOINTED LEGS? Nearly 700,000 kinds of animals belong in this group of invertebrates. Though you have not learned the name of the group, you know some animals that are included in it. Flies, mosquitoes, ants, bees, wasps, beetles, crickets, grasshoppers, butterflies, moths, fleas, lice, spiders, daddy-longlegs, ticks, crayfish, crabs, lobsters, and centipedes all belong in this group. These animals seem to be different, but they all have three characteristics of structure that are alike.

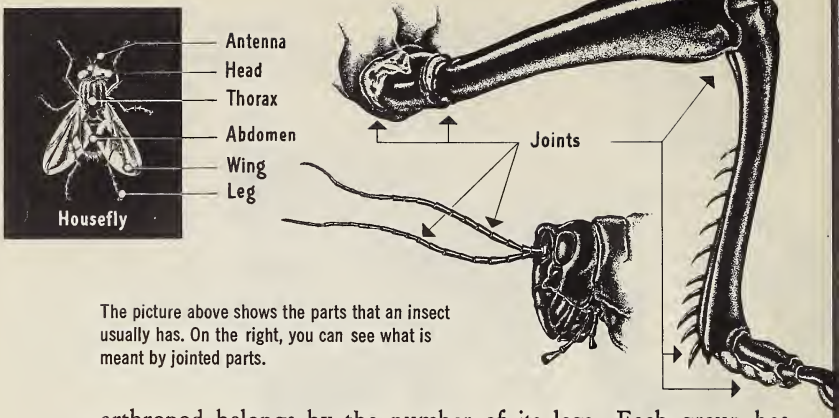
Every animal in this group has joints in its legs. All the other *appendages* (ə pen′ dij iz), or parts that extend out from the body,



Crustaceans

have joints in them, too. Scientists group together all the invertebrate animals with jointed appendages and call them *arthropods* (är′ thrə podz), which means animals with jointed legs. Of course most vertebrates have joints in their appendages, but these are jointed in a different way. Arthropods have no skeletons inside their bodies. Instead, their skins contain a hard, horny material called *chitin* (kī′ tin). This covers the body like a suit of armor and forms an outside skeleton. The inside parts of the body are attached to it. Even the body of an arthropod is made up of sections, or *segments,* with joints between them. Some of the segments are grown together to form a head. In some arthropods there are two main divisions: the thorax and the abdomen. Each division is made up of segments. Some arthropods have the head and thorax in one piece. Others have the thorax and abdomen in one piece.

The arthropods can be separated into four smaller groups: insects, *arachnids* (ə rak′ nidz), *crustaceans* (krus tā′ shənz), and many-legged animals. You can usually tell in which group an



The picture above shows the parts that an insect usually has. On the right, you can see what is meant by jointed parts.

arthropod belongs by the number of its legs. Each group has some characteristics of structure that the others do not have. But all the groups have the three characteristics of arthropods: (1) jointed legs and other appendages, (2) an outside skeleton containing chitin, and (3) a body made up of segments.

Flies, mosquitoes, ants, bees, wasps, beetles, crickets, grasshoppers, butterflies, moths, fleas, and lice are all insects. This group includes over 600,000 kinds of arthropods. So there are more kinds of insects than of all other animals. Yet you can easily tell an insect when you see one. Every insect has six legs, arranged in three pairs. It also has two feelers, or antennae (an ten′ ē), on its head. Its body has three distinct divisions: head, thorax, and abdomen. In fact, that is what gives this group of arthropods its name. Insect means cut in or divided.

Most full-grown insects have one or two pairs of wings, but some kinds have no wings. All insects breathe air through openings along the sides of their bodies. Sometimes people think that young insects are worms. But if you find a wormlike animal with a segmented body and six legs on the front part, it is not a worm. It is really a larva (lär′ və), or an insect in the second stage of its life. Caterpillars are the larvae (lär′ vē) of butterflies and moths. Grubs are the larvae of beetles, and maggots are the larvae of flies.

The arachnids include about 30,000 kinds of arthropods. Though the name of this group may be new to you, you already know some of the animals. Spiders, daddy-longlegs, ticks, mites,

and scorpions are all arachnids. Many people mistake arachnids for insects, but you can easily tell them apart. When full grown, all arachnids have eight legs, arranged in four pairs. (A few kinds have only six legs when young.) Their bodies have only two distinct divisions, because the head and thorax are in one piece. Arachnids never have wings or antennae.

There are about 20,000 kinds of crustaceans, and most of them live in water. The ones that you will see most often in fresh water are crayfish. Among the kinds that live in salt water are crabs, lobsters, shrimps, and barnacles. From their names you might think that water fleas and sow bugs were insects, but they are really tiny crustaceans. A crustacean always has more than eight legs and fewer than thirty legs, arranged in pairs. It also has two pairs of antennae. Its head and thorax are usually in one piece. Crustacean means crusted animal, and this group of arthropods is well named. The larger crustaceans have lime as well as chitin in their skeletons. This makes their outer covering very stiff and strong.

Centipedes and millipedes belong in the group of many-legged animals, which includes about 2000 kinds of arthropods. All of them live on land. People often call these animals hundred-legged worms (centipedes) and thousand-legged worms (millipedes). Though they have wormlike bodies made up of many segments that are much alike, they are true arthropods, not worms. You may see them on the ground where there is decayed wood or leaves. The house centipede lives in basements and cellars, feeding on insects. It has thirty long legs, arranged in pairs. Most of the other many-legged arthropods have short legs. They may have from thirty to 400 legs, arranged in pairs on the segments.

SELF-TESTING EXERCISES

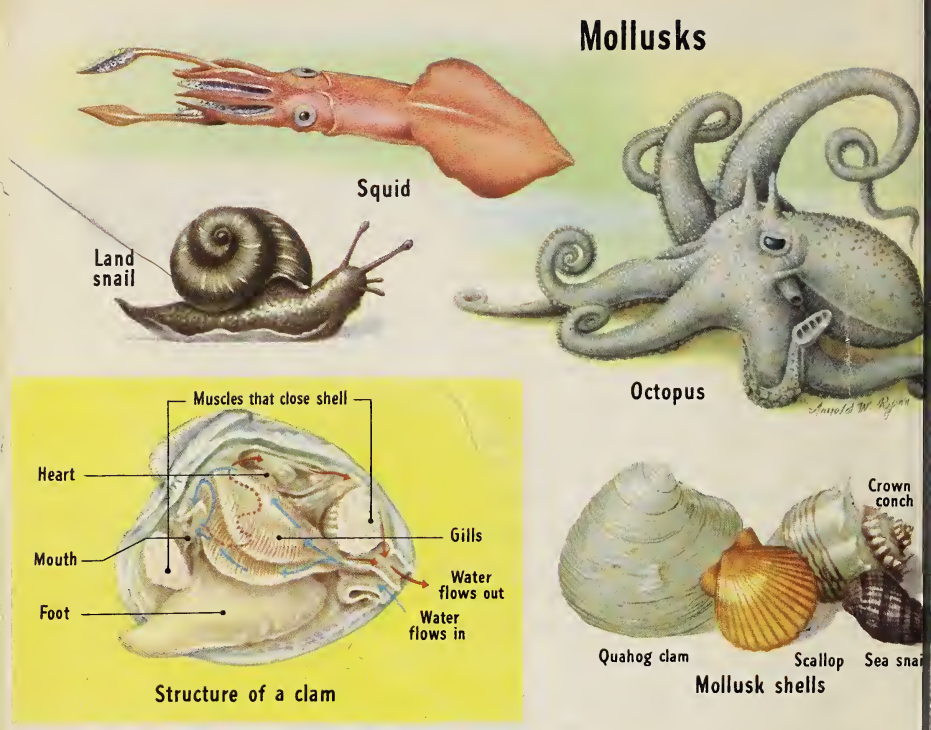
1 What do we mean by an invertebrate?

2 State three characteristics of structure that all arthropods have.

3 **a** What are the four groups of arthropods?

b Name at least two kinds of animals that belong in each group.

4 How can you tell in which of the smaller groups an arthropod belongs? Give examples to explain your answer.



WHAT GROUP OF ANIMALS HAS SOFT BODIES? The animals that you are now going to study make up the second largest group of invertebrates. Scientists put almost 80,000 kinds of animals in this group. It includes clams, oysters, scallops, shipworms, snails, slugs, squids, octopuses, cuttlefish, and nautiluses. Every animal in this group has a soft, fleshy body. From this characteristic the group gets its name. *Mollusk* comes from a word that means soft. Many mollusks have hard shells outside their bodies, but some kinds have shells inside their bodies. Other kinds have no shells. Unlike the arthropods, the mollusks do not have segmented bodies or jointed appendages.

Clams, oysters, scallops, and shipworms live in water. They have a shell in two parts. These parts are held together by a strong muscle, and they can open or close like a hinge. The picture on this page shows the structure of a salt-water clam. On one side is a short, double tube that opens into the water. Tiny moving hairs inside

the clam make a stream of water flow into one tube and out of the other. Small plants and animals are swept into the tube along with the water. This food goes into the mouth of the clam. Then the water, without the food, goes through gills that take air from the water. From the gills the water goes out of the other tube. Near the lower edge of the shell is a large, fleshy foot. Of course it is not like your foot, but the clam can use it to move slowly along. Oysters do not have this foot, and so they cannot move by themselves. Otherwise their structure is much like that of clams.

Snails and slugs look very different from clams and oysters. For one thing, they have heads. On their heads are four appendages. One pair is used as feelers, and the other pair has eyes on the ends. These appendages can be bent and moved around, but they have no joints. A snail can stay protected inside its twisted shell. Or it can push its body out of the shell and crawl along with the shell on its back. A slug either has no shell, or the shell is

inside its body. Snails and slugs move in a strange way. The bottom of the foot pours out a slimy material. Then ripples pass from one end of the foot to the other and move the animal along the slippery path that it has made. Some snails and slugs have rough, horny tongues that can do much damage. A snail can even drill a hole right through a clam or oyster shell and then eat the soft body inside.

If you live near the ocean, you may have seen squids. Fishermen often use them for bait. A squid has its shell inside its soft body. It has two large eyes and usually ten long arms with suckers on them. With its sharp beak it can cut and tear food. The giant squid, which lives in the north Atlantic Ocean, is the largest invertebrate animal. Its body may be 8 feet across and 50 feet long, and its arms may be 30 to 40 feet long. The huge sea serpents that people sometimes think they see are probably giant squids. The cuttlebone that people put in bird cages is really the inside shell of a cuttlefish, which is not a fish at all. It is a mollusk that looks much like a squid.

An octopus, or devilfish, is another kind of mollusk that is like a squid. But it has no shell inside its body and only eight long arms with suckers on them. These arms help the animal move around and also hold its prey. Giant octopuses 28 feet across have been caught in the Pacific Ocean. But even a huge octopus probably would not attack a boat, though it might be dangerous to a swimmer. A squid or an octopus can move surprisingly fast by jet propulsion. It squirts a stream of water out of a tube, and this pushes its body through the water.

SELF-TESTING EXERCISES

1 State the characteristics of structure that mollusks have.
2 Name at least three very different mollusks and tell how each one is different from the others.

WHAT ANIMALS ARE WORMS? Many people think that any wriggling animal with a long, soft body is a worm. But you already know that two kinds of wormlike animals are not really worms. Either they are insect larvae such as caterpillars,

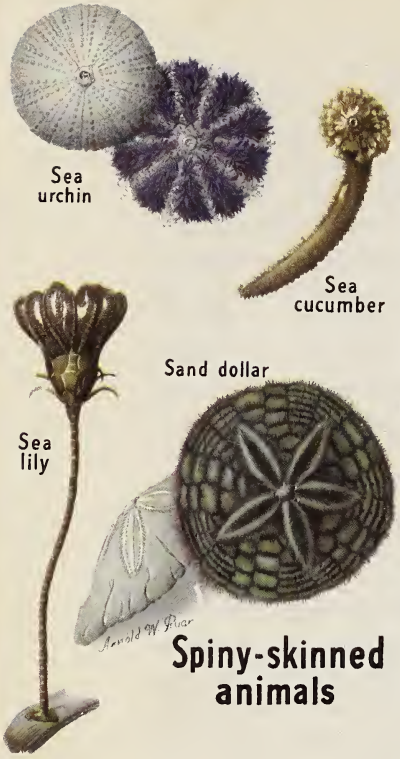
grubs, and maggots. Or they are many-legged arthropods such as centipedes and millipedes. Scientists have discovered and named about 15,000 kinds of worms. All of them have long, soft bodies. But unlike insects and other arthropods, they have no skeletons or legs. Instead of just one group of worms, there are actually three separate groups: segmented worms, roundworms, and flatworms. The name of each group tells its outstanding characteristic.

The worms that you know best are earthworms. They are also called angleworms, night crawlers, and fishworms. If you examine the body of an earthworm, you will see that it is made up of segments. So an earthworm is a segmented worm. Earthworms burrow through the soil by eating it. As the soil passes through their bodies, they take out plant and animal materials for food. Then the parts that they do not use as food pass out of their bodies. On moist nights earthworms come out of the soil and eat dead leaves and other decaying material. Giant earthworms that grow to be 11 feet long live in the warmer parts of the world.

Sand worms, tube worms, and leeches are also segmented worms. If you have ever gone swimming in fresh water, you may have seen leeches, or bloodsuckers. They attach themselves to the body of a person or animal and suck blood from it. Bleeding was once a common way to treat all kinds of diseases that people had. Leeches were often used to draw out the blood.

Roundworms have a long, round, smooth body that is pointed at the ends. It has no segments. Most roundworms are too small to be seen with your naked eyes. But if you look at some soil or mud through a magnifying glass, you will probably see some roundworms thrashing about. Many roundworms are *parasites*. They live in other animals or plants from which they get their food. The ones that we hear most about are those that get inside our bodies or inside our pets and farm animals. The hookworm usually gets into the body through bare feet. Another roundworm, called *trichina* (tri kī′ nə), usually gets into the body in raw or poorly cooked meat. Both of these worms can cause serious diseases.

Flatworms have flat bodies with no segments. If you put a piece of raw meat in a stream or pond, perhaps you can catch some flatworms. They are dark-colored and about a quarter of



an inch long. Like the roundworms, many flatworms are parasites. Tapeworms may get into the body in raw or poorly cooked beef or pork. Once inside the body, a tapeworm may grow to be several feet long. Much more dangerous are small flatworms, called flukes, that get into the liver, blood tubes, and other parts of the body. In this country, the liver fluke is a serious parasite in sheep.

SELF-TESTING EXERCISES

1 State the characteristics of structure that worms have.

2 Name the three groups of worms and tell how each group differs from the others.

WHAT ARE SOME OTHER GROUPS OF ANIMALS? Besides the arthropods, mollusks, and worms, there are several other groups of invertebrates. But you are going to study only three of them. All the animals in these three groups live in water. Many of them have such queer names and look so strange that you would hardly think they were animals. Some of them even look like plants.

Starfishes, sea urchins, sand dollars, sea cucumbers, brittle stars, and sea lilies belong in the first group. It includes about 5000 kinds of animals. All of them have a spiny or leathery skin. We usually call them spiny-skinned animals. They move by pumping water into and out of hundreds of tiny feet with suckers on the ends. The suckers help drag the body along in the water. No other group of animals has this way of moving. A starfish can pry

open an oyster or clam shell with its suckers and then eat the soft body of the animal inside.

In the second group scientists put jellyfishes, coral polyps, sea anemones, and hydras. All together, there are about 5000 kinds of animals in this group. Each of them is just a hollow, sac-like body. The mouth is the only opening into the intestine. Around the mouth are appendages that contain poison. No other group of animals has them. A tiny hydra only one eighth of an inch long can sting and kill other small animals. Jellyfishes sometimes grow to be 8 feet across, but even much smaller ones can give a swimmer serious wounds. Coral polyps give off lime, which forms a stony cup. Where they live together in large groups, or colonies, they build up huge masses of limestone on the bottom of the ocean. Many of the islands and reefs in the Pacific Ocean were made in this way.

The third group includes about 3000 kinds of animals called sponges. Some of these are the fresh-water sponge, urn sponge, red-bearded sponge, and Venus's flower basket. Full-grown sponges do not move around. They are always attached to something. So sponges seem more like plants than animals. The sponge that we use for washing is really made of the dried skeletons of many small sponge animals that once formed a colony.

A living sponge looks and feels much like a slippery piece of raw liver. Its body may have one or more large openings. All

Sponges

Though a protozoan is just one cell, different kinds have very different shapes. Here are a few kinds as seen through a microscope.

over its body there are thousands of tiny holes. No other group of animals has this characteristic of structure. Water carries food and air into the body through these tiny holes. Then the water goes out through the large openings.

SELF-TESTING EXERCISES

1 **a** State the important characteristics of each of the three groups you have just studied.

b Name at least two animals that belong in each group.

2 What do we mean by a colony of animals? Give an example.

WHAT ARE THE SIMPLEST ANIMALS? Some animals are so tiny that there may be hundreds or even thousands of them in a drop of water. Scientists call them *protozoans* (prō′ tə zō′ənz), which means first animals. With your naked eyes you can just barely see the largest protozoans. Most of them are much too small to be seen without a microscope. Though there are about 15,000 kinds of animals in this group, they are all alike in one way. Each protozoan is made up of just one cell.

You probably know that all living things are made up of cells. The groups of animals that you have studied so far have many cells in their bodies. Different cells do different things such as moving or digesting food. But the one cell of a protozoan moves,

takes in food, and does all the other things that the animal can do. So protozoans are said to be the simplest animals.

Protozoans are found in every pond, lake, or stream. Stagnant water swarms with them. Even drinking water may have a few harmless ones in it. These tiny one-celled animals can stay alive under almost any condition. When there is not enough food and water, they dry up into tiny bits and blow about in dust. Then when they can get water and food, they become active once more. They grow very fast and divide in two again and again until there are millions of them. Protozoans eat the tiny plants called bacteria that make dead animals and plants decay. Then slightly larger animals eat the protozoans.

Most animals have protozoans inside their bodies. Insects called termites cannot digest the wood they eat, but inside their bodies are protozoans that can digest the wood. Probably there are protozoans living inside your body without doing you any harm. But a few kinds cause serious diseases such as malaria, African sleeping sickness, and dysentery.

SELF-TESTING EXERCISES

1 How are protozoans different from all other groups of animals?
2 Where are protozoans found? Mention as many places as you can.

PROBLEMS TO SOLVE

1 Look at the picture on page 35. In what group does each invertebrate belong? Give reasons for your answers.
2 A measuring worm has a segmented body and three pairs of legs. In what group of animals do you think it belongs? Explain.
3 If a bunch of dry leaves or grass is kept in water for a week or two, protozoans will usually be found in the water. How did they get there?
4 Crabs, lobsters, shrimps, oysters, and clams are often called shellfish. Do they belong in the same group as fish? Give your reasons.
5 No invertebrate animal is as large as the biggest vertebrate animal. Why do you think this is true?
6 Which animals are most alike, the different kinds of vertebrates or the different kinds of invertebrates? Give examples to explain your answer.

Plants have many different shapes and sizes. Here are just a few of the thousands of different kinds of plants. What differences can you find?

3 What are the main groups of plants?

Scientists have discovered and named over a million kinds of living things, but only about 340,000 kinds are plants. Where you live, there are probably just a few thousand kinds of plants. Even if you are looking for them, you will not notice more than a hundred kinds. Yet plants are very important. Only plants can make their own food, and not all of them can do that. All other living things get their food directly or indirectly from the kinds of plants that do make food.

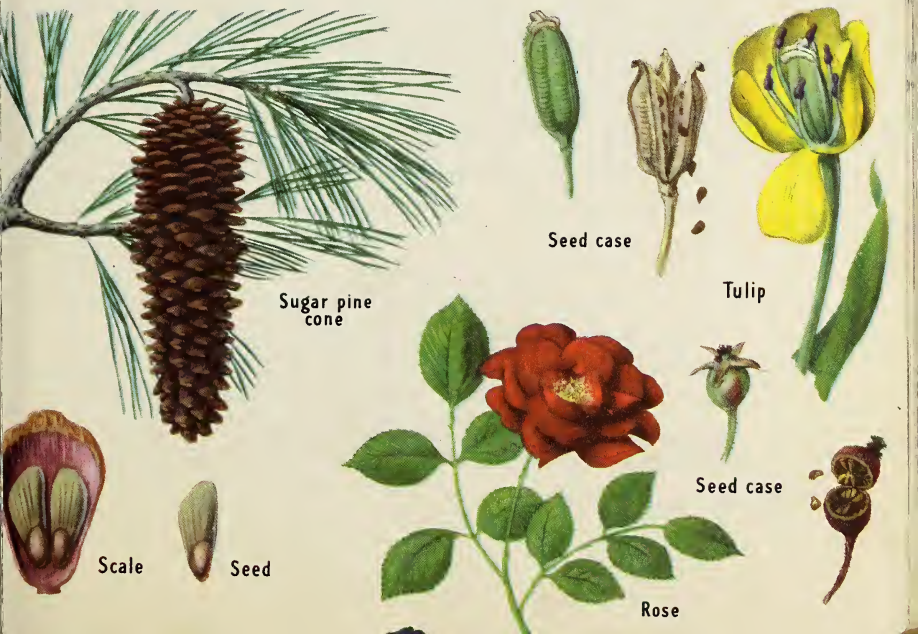
Like animals, plants are classified according to their characteristics of structure. But most plants are so different from animals that we must use different characteristics to classify them. You know that animals can be divided into two big groups: those that have backbones and those that have not. Plants can also be divided into two big groups: those with seeds and those without. Each big group can then be divided into smaller groups that have different characteristics of structure.

WHAT GROUPS OF PLANTS HAVE SEEDS? When you think of a plant, it is probably one that has seeds. This is not surprising, because most of the plants that you know are seed plants. Over 200,000 kinds of plants belong in this big group. So there are more kinds of seed plants than of all other kinds. All trees and shrubs, all crop plants and vegetables, all garden flowers and wild flowers, and all grasses and weeds are seed plants. From them we get almost all the plant food that we eat or feed to our farm animals. Wood, paper, cotton, and linen all come from these plants.

Seed plants grow in soil and fresh water. You will find them in deserts and swamps, but very few of them grow in the sea. The smallest seed plants are tiny, floating duckweeds, which are about a quarter of an inch across. The largest seed plants are the giant sequoias (si kwoi′ əz) of California. These huge trees, which grow 350 feet tall, are the biggest living things on the earth.

Seed plants have leaves, stems, and roots. Tubes that carry water run from the roots up through the stems into the leaves. But you will find that some other plants have the same character-

Plants like the sugar-pine tree have cones. The seeds grow at the lower end of the scales of the cone. When the scales spread apart, the seeds are shed. In plants that have flowers, part of the flower becomes a seed case in which the seeds are enclosed.



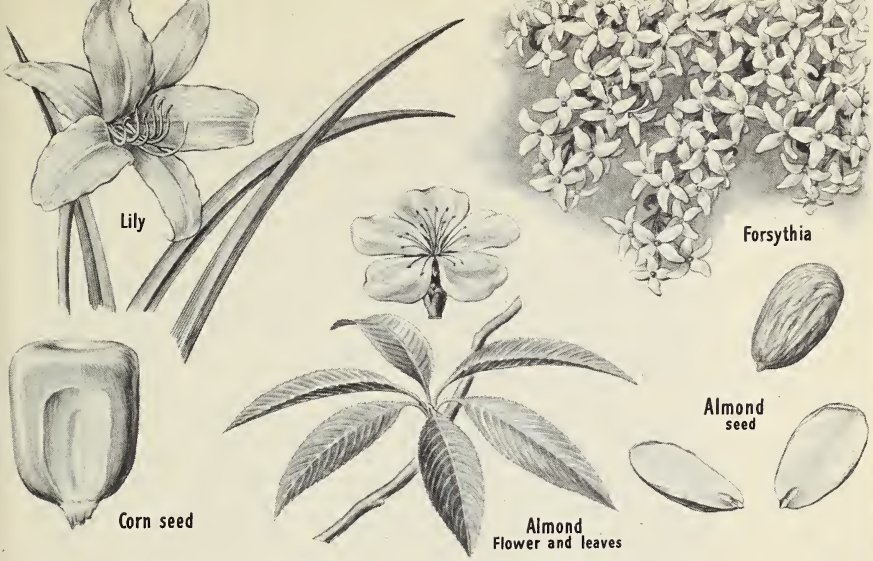
istics of structure. So the most important characteristic of seed plants is their seeds. No other plants have them. You know that a new plant can grow from a seed. Inside the covering of a seed, there is a tiny young plant with food stored around it. The food helps the plant start growing.

Whenever you see a plant with flowers, you can tell that it is a seed plant. For flowers are usually followed by seeds. However, many seed plants have flowers that are so small or so different from the usual kinds that you probably would not think of them as flowers at all. There are also plants such as pine trees that have their seeds in cones instead of flowers. So scientists divide the big group of seed plants into two other groups: those with cones and those with flowers.

There are only about 650 kinds of seed plants with cones. Most of them are trees with needle-shaped leaves that stay on all the year round. Some of the trees that belong in this group are the pine, fir, spruce, hemlock, cedar, cypress, and sequoia. Though this is a small group, the plants that belong in it are important. From them we get lumber, paper pulp, turpentine, and resins. We also use some kinds for Christmas trees.

The seed plants that you probably see most often are those with flowers. All together, there are about 200,000 kinds in this large group. It includes all garden flowers and wild flowers, all fruits and vegetables, all grasses, grains, and weeds. In this group also belong all trees and shrubs that lose their broad leaves in the autumn. The flowering plants can be separated into two smaller groups: those with one-part seeds and those with two-part seeds.

The first group of flowering plants is made up of about 60,000 kinds. The seeds of these plants cannot be easily pulled apart into halves. The veins in the leaves usually all run in the same direction, as in a lily leaf or a blade of grass. The petals and other parts of the flowers are in threes (three, six, or twelve). They are never in fives. Plants that belong in this group are wheat, corn, rye, oats, barley, rice, sugar cane, wild grasses, bamboo, date palm, asparagus, onion, pineapple, banana, lily, tulip, hyacinth, and lady's-slipper. You can see that all of our grains and some of our other food plants belong in the group with one-part seeds.



The parts of these plants show some of the characteristics of two big groups of flowering plants. Study the picture carefully and tell in which group you would put each plant.

The second group of flowering plants includes about 140,000 kinds. The seeds of these plants can be separated into halves. The veins in the leaves form a network, as in an oak or maple leaf. The petals and other parts of the flowers are in fours or fives (four, five, eight, ten, or many). They are never in threes. In this group are peas, beans, peanuts, walnuts, apples, pears, peaches, plums, cherries, strawberries, cabbages, turnips, carrots, radishes, roses, sunflowers, dandelions, oaks, elms, willows, poplars, maples, and beeches. As you can see, most of our fruits and vegetables as well as our shade trees belong in the group with seeds that can be split into two parts.

SELF-TESTING EXERCISES

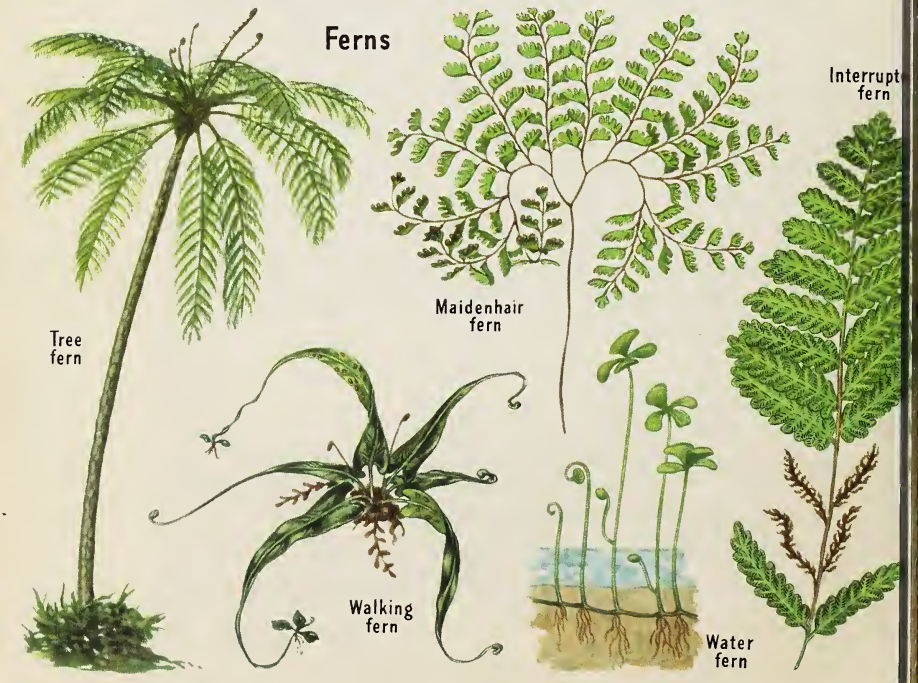
1 **a** What are the two main groups of seed plants?
b Name at least four plants that belong in each group.

2 **a** One group of seed plants can be separated into two smaller groups. State the characteristics of each of these groups.
b Name at least six plants that belong in each group.

3 Why are the seed plants important? Give as many reasons as you can.

WHAT GROUPS OF PLANTS HAVE NO SEEDS? Before you even studied the seed plants, you knew some things about them. And from what you have just learned, you can understand why the seed plants are important. They not only form the biggest group of plants, but from them we get many of the things that we need and use. However, the plants that have no seeds include several interesting groups. Each group has some characteristics of structure that the others do not have. Though there are only about 140,000 kinds of plants without seeds, some of the kinds are very important as you will see.

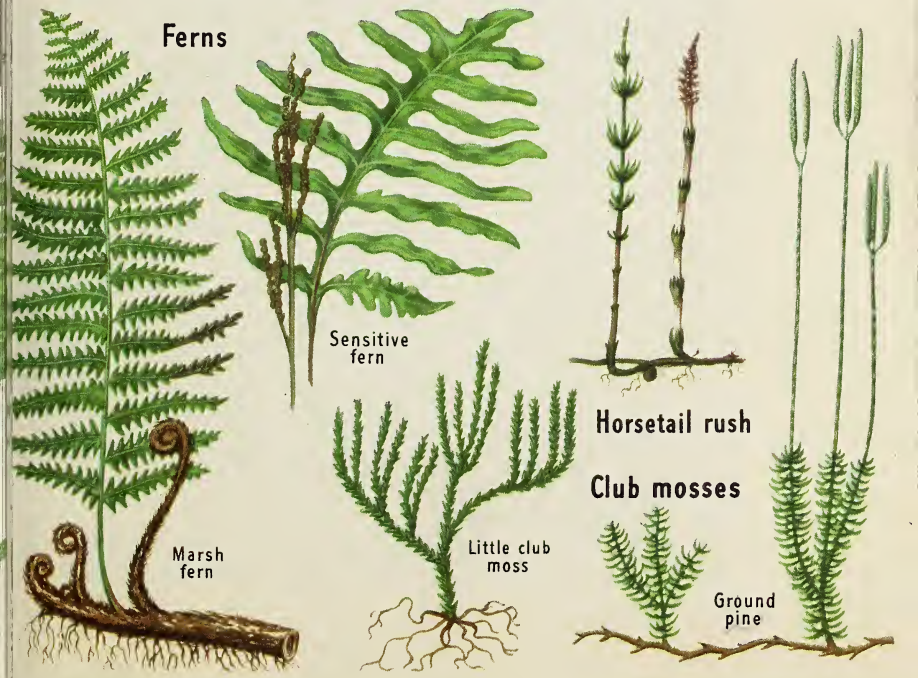
The smallest group of plants without seeds includes the ferns. Only about 8000 kinds of plants belong in this group. So it is not very important now. But long ago when the reptiles called dinosaurs ruled the earth, the land was covered with fern plants as big as many of the trees that we have today. Most of our coal was made from the dead bodies of these fern plants. Without them, we would not have one of our most important fuels. Tree-like ferns 40 feet tall still grow in the warmer parts of the earth,



but most ferns are much smaller. The kinds that you are likely to see seldom grow more than a few feet tall.

Like the seed plants, all ferns have leaves, stems, and roots. They also have tubes that carry water up from the roots through the stems into the leaves. The green part of a fern that you see is usually just the leaf. The stems of most ferns grow along or under the ground. Only the treelike ferns have stems above the ground. If you examine a fern leaf, you will see that it is divided into many parts, or leaflets. As a young fern leaf grows, it unrolls from the tip. No other plants have leaves that grow in this way.

You know that ferns do not have seeds. How then can they make more new plants like themselves? You probably know that ferns and some other plants have spores instead of seeds. Like a seed, a spore can grow into a new plant. But unlike a seed, a spore does not contain a tiny young plant with food stored around it. A spore is usually just one cell. If you look carefully at the leaves of some ferns, you will probably find rows of little brown dots on the backs or edges of the leaflets. Other ferns have these dots on



special leaflets or on stalks. The spores are produced in these little dots. These spores look like tiny bits of brown dust. They are much smaller than any seed that you have ever seen. When the little dots burst open, the spores are scattered. They blow about in the air until they fall to the ground. Then if there is enough food and water, each spore can grow into a new plant.

In the same group as the ferns, scientists put the plants called horsetails and club mosses. These plants do not look much like ferns, but they have the same characteristics. All of them have leaves, stems, roots, water tubes, and spores. One kind of horsetail has stiff, rough stems, which campers sometimes use for cleaning pots and pans. For this reason, these plants are also called scouring rushes. Club mosses are low evergreen plants with small leaves. Because they look somewhat like little pine trees, they are sometimes called ground pines. But in spite of their names, they are neither pine trees nor mosses. They belong in the same group of plants as the ferns.

True mosses belong in another group of plants that have no seeds. This group includes about 23,000 kinds of plants. You have probably seen mosses growing on rocks and soil in moist woods and old fields or on tree trunks and rotting logs. After a long spell of wet weather, you may find moss plants coming up almost anywhere, even on the shady side of buildings or in the cracks of sidewalks. Mosses are seldom more than a few inches tall. They often grow in clumps, forming a soft, green carpet.

Like the ferns, all moss plants have spores instead of seeds. The spores grow in little holders that you can see sticking up from the tops of the plants. When the cover falls off the holder, the spores go flying away in the air. Mosses seem to have tiny leaves and stems. However, they are not like the leaves and stems of ferns and seed plants, because they have no tubes running through them. So scientists do not consider them true leaves and stems. Mosses also have threadlike parts that grow into the soil and hold the plants in place. Yet these parts are much too simple to be considered true roots.

With the mosses scientists put the plants called liverworts, which means liver plants. Many of them are shaped like little

green livers. But some of them look so much like mosses that only an expert biologist can tell them apart. Liverworts are usually small, flat plants that grow in damp, shady places. Like the mosses, they have spores instead of seeds. They do not have true leaves, stems, or roots.

Besides the moss plants, there is another group of plants that have no seeds, leaves, stems, or roots. However, the plants in this group are much simpler than a moss plant. Because they have nothing but a body, we call them the all-body plants. This group of plants includes about 110,000 kinds. So you can see that it is the largest group of plants without seeds. Scientists divide the all-body plants into two smaller groups. To do this, they use a characteristic of structure that is very different from any used up till now. Let us see what it is.

Except for a few kinds of seed plants, every plant in all the groups that you have studied so far can make its own food. To do this, a plant must contain a green material called chlorophyll (klō′rə fil). Most seed plants, all fern plants, and all moss plants have chlorophyll. Some kinds of plants in the group that you are now going to study also have this material, but most kinds do not. So scientists use this characteristic to divide these plants into two groups: those with chlorophyll and those without. The ones that have chlorophyll are called *algae* (al′ jē), while those that have no chlorophyll are called fungi (fun′ jī). An *alga* (al′ gə) can make its own food, but a fungus (fung′ gəs) must get its food from other plants or from animals.

Scientists have discovered and named about 20,000 kinds of algae. They grow in water, on damp soil and trees, and in greenhouses. From the very largest kinds the group gets its name, for algae means seaweeds. These plants are found only in the oceans, where some kinds grow to be more than 100 feet long. However, most kinds of algae are much smaller than the seaweeds. Many are so tiny that they cannot be seen without a microscope unless they are in colonies with thousands of other plants like themselves.

Perhaps you have seen a colony of algae growing on the damp, north side of a tree or an old building. It looks like a green stain or some old green paint. The green scum on ponds is really made

Mosses and liverworts
Liverworts
Bacteria
Molds
Yeasts
Mosses
Slime molds
Algae
Mushrooms
Green algae
Fungi
Red algae
Brown algae

of many tiny algae. If you look at some pond scum with a microscope, you will see many little plants that look like green threads. Sticking to the threads are still smaller green and brown plants. All of them are algae. The larger algae, such as the seaweeds, are made up of many cells. Like the fern and moss plants, these algae have spores. However, the smaller algae are made of just one cell. They make new plants by dividing in two as the protozoans do.

Some kinds of seaweeds are used to make materials needed for ice cream, jellylike candies, and the special jelly on which scientists grow germs to study. Small algae are important food for the little animals that fish eat. If fertilizer is thrown into fish ponds, the algae grow better. Then the little animals have plenty of food, and so do the fish.

The other group of all-body plants includes many more kinds than the algae. All together, there are about 90,000 kinds of fungi. Mushrooms are probably the ones that you know best. From these plants the group gets its name, for fungi means mushrooms. In this group scientists also put molds, yeasts, and bacteria. The larger fungi, such as the mushrooms and molds, are made up of many cells and have spores. The small fungi, such as the yeasts and bacteria, are made of just one cell. Unless they are in colonies with thousands of plants like themselves, you cannot see them without a microscope. To make a new plant, a yeast cell pushes out a little swelling called a bud. The yeast bud breaks off and grows into a new plant. Bacteria make new plants in the same way that the one-celled algae do. They just divide in two.

Fungi are far more important than all the ferns, mosses, and algae in our world. Some are helpful, while others are harmful. Certain kinds of mushrooms are very good food. In fact, they are almost as nourishing as meat. Other kinds are extremely poisonous. So it is safer to eat the mushrooms that you buy in stores than the ones that you pick. We use yeast to raise bread and to make alcohol for important chemicals. A cake of yeast has thousands of tiny yeast plants in it. They are mixed with flour and pressed into a cake. When the yeast plants are put in moist, warm bread dough, they multiply very fast. As they multiply and

grow, they give off carbon-dioxide gas. Bubbles of this gas swell up and make the dough rise. However, not all kinds of yeasts are helpful. Some kinds can cause disease.

Molds of many kinds grow on stored food such as bread, meat, fruits, vegetables, grains, and hay. They even grow on damp cloth and leather. Many of these fungi are parasites, and they cause diseases in other plants and animals. Almost every kind of crop and garden plant may have some disease caused by fungi that grow on leaves, stems, or roots. Some fungi grow on wheat and oat plants, where they produce rust-colored masses of spores. They are called rust fungi. Others turn the heads of wheat and corn into black masses of spores. These are called smut fungi. The disease known as athlete's foot is caused by a tiny mold plant that gets into cracks in moist skin. But not all molds are harmful. From one kind scientists get the drug penicillin (pen′ ə sil′ ən), which cures many serious diseases.

The very smallest fungi are the bacteria. These tiny one-celled plants are everywhere. But until about 300 years ago, no one even knew that they existed. Then after the microscope was invented, people began to see bacteria. Not until about 100 years ago did scientists discover that some kinds of bacteria were germs. Now we know that different kinds of bacteria cause whooping cough, scarlet fever, diphtheria, pneumonia, typhoid fever, tuberculosis, and many other diseases.

However, not all kinds of bacteria are germs. Most kinds are harmless, and many kinds are helpful. Some bacteria change cider into vinegar, and some help make cheese. Other bacteria make dead animals and plants decay. In this way, materials that growing plants need are added to the soil. Still other bacteria grow on the roots of some kinds of plants and make chemicals that plants must have to grow. Scientists are quite sure that many plants and animals could not live as they do without bacteria to help make the soil richer.

SELF-TESTING EXERCISES

1 **a** Name the main groups of plants that have no seeds.

b State the important characteristics of each of these groups.

In which big group of seed plants does each of these garden flowers belong? Explain your answer.

2 How is the largest group of plants without seeds separated into two smaller groups?

3 What is the most important group of plants without seeds? Give reasons for your answer.

4 Name the groups of plants that have these characteristics: **a** Leaves, stems, and roots. **b** Spores. **c** Tubes that carry water. **d** Chlorophyll. **e** Seeds. **f** Body made of one cell or many cells.

PROBLEMS TO SOLVE

1 Which could you best get along without, plants or animals? Explain your answer.

2 Why do you think that fungi are often parasites on other plants and animals?

3 Do you think that the only harmful plants are fungi? Give some examples to explain your answer.

4 If you were a scientist, how would you go about deciding in what group a strange plant belongs?

5 Try to examine at least one plant in each of the groups that you have studied. Does it have all the characteristics of the group? What other characteristics does it have?

4

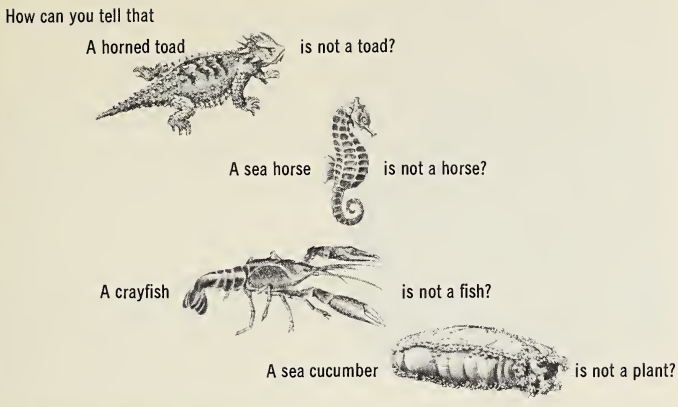
How do scientists classify living things?

WHY DO SCIENTISTS CLASSIFY LIVING THINGS? Classifying things is an everyday activity, and you have surely noticed many examples of it. In the kitchen your mother classifies the dishes. She puts all the cups together, all the saucers together, all the plates together, and so on. A grocer classifies the things in his store. He keeps the fresh fruits and vegetables in one place, the canned and packaged foods in another place, and so on. Probably without even knowing it, you have been classifying things most of your life.

But why do we classify things? It is the best way that we have to keep track of them. If things are arranged in order, we know where to find them. Besides, when we group together things that are alike in some way, we can talk about them more easily because we can give a name to each group. Scientists classify living things for the same reasons that we classify other things. Long ago, scientists found out that they could not talk with each other about what they had learned or tell the world what they had discovered unless they had exact names for things. They want to know what each kind of living thing is. So they need to have a name which means that living thing and nothing else. Classifying living things makes it possible to give each kind a name.

Suppose that you say, "I just saw an animal on a plant eating another animal." That does not give me a very clear idea of what you saw, because there are more than a million kinds of animals and plants. Perhaps you saw a blacksnake on an oak tree eating a young robin, or maybe you saw a sparrow on a morning-glory vine eating a caterpillar. There are many things that you might have seen. But if you tell me that you saw a bird on a tree eating an insect, I have a fairly good idea of what you saw.

When you mention the names of the groups in which the animals and the plant belong, at once I have a picture of what you mean. I know that a bird has feathers, two legs, and two wings. I also know that an insect has six legs, two feelers, and three main sections in its body. And I know that a tree is a seed plant with



What groups do these animals belong in?

leaves, a stem, or trunk, and roots. Now suppose that you tell me that the bird was a woodpecker, the insect a beetle, and the tree a pine. If I understand what you mean by each of these names, I have a very clear idea of what you saw.

However, the same kind of living thing often has many common names. Ragweed is also known as Roman wormwood, bitterweed, wild tansy, hayweed, carrotwood, hogweed, and stammerwort. A bird that is usually called the flicker is also known as the golden-winged woodpecker, the yellowhammer, and the high-hole. What is even more confusing, the same name is sometimes used for living things that are very different. In the northern part of our country, a gopher is an animal that looks somewhat like a squirrel but lives in the ground. In the southern part of our country, a gopher is a land turtle!

Even when many people use the same name for a living thing, the name usually does not tell in what group the living thing belongs. In fact, the name may even suggest an entirely different group. A horned toad is a reptile. It does not belong with toads in the group of amphibians. Water fleas and sow bugs are crustaceans, not insects. A shipworm is really a mollusk, and a measuring worm is the larva of an insect. Crayfish, cuttlefish, starfish, and jellyfish are not fish at all. They are not even vertebrate animals. Each one belongs in a different group of invertebrates. Sea

cucumbers and sea lilies are animals, not plants. But beggar's-lice, or beggar's-ticks, is a plant, not an animal.

You can easily see how mixed up things would be if scientists had not worked out a plan for classifying all the kinds of animals and plants and for giving each kind a name of its own. When you consider that more than a million kinds of living things have been discovered, you can imagine what a big job it has been to classify and name all the kinds. For many years, scientists have patiently studied animals and plants and collected the facts about them. But scientists are not just fact collectors. They try to fit facts together so as to give us a better understanding of our world. The plan of classification that scientists use fits together many facts about living things.

SELF-TESTING EXERCISES

1 What are the advantages of grouping together things that are alike in some way? Give an example to explain your answer.
2 State at least two reasons why scientists classify living things.
3 Explain why scientists need a plan for classifying and naming animals and plants.

WHAT PLAN OF CLASSIFICATION DO SCIENTISTS USE? Unless you expect to become a biologist, you will not need to learn exactly how living things are classified. However, you should know something about the plan of classification that scientists use. Over 2000 years ago, people tried to classify the different kinds of animals and plants. Many plans were thought up, but none of them worked very well.

In some plans, living things were grouped according to their uses. Those that were used for food were put in one group, those that were used in medicine in another group, and so on. Many kinds of animals and plants were left out entirely, because no use for them was known. In other plans, living things were grouped according to where they lived. Those that lived in water were put in one group, and those that lived on land in another. But some living things did not fit into either group, because they lived both in water and on land.

When Linnaeus traveled in Lapland, he often dressed in the same kind of warm clothing worn by the Laplanders.

From what you have learned about the main groups of animals and plants, you can see why none of these plans worked very well. They grouped together living things that are really very different, and they left out living things that did not seem to fit into any group. For hundreds of years, people could not work out a good plan of classification, because they did not know enough about animals and plants. They had not learned how to study living things as scientists do today.

Then about 225 years ago, two students met at the University of Uppsala (up′ sä lə) in Sweden. They were Carl Linnaeus (li nē′ əs), and Peter Artedi (är tā′ di). As they grew better acquainted, they became very good friends. Linnaeus liked to study plants, and Artedi was interested in fish. They often discussed the trouble that scientists had when they tried to classify living things. After many talks, the two friends decided to work out a better plan of classification. Linnaeus was to begin with the plants, while Artedi took the fish. But Artedi died a few years later and Linnaeus carried on the work alone. During his lifetime, he classified and named several thousand kinds of living things. Of course, that was hardly more than a start. Yet it was a real start because of the plan that he used.

Linnaeus classified living things according to their structure. He grouped together living things whose bodies were alike in some way. He also gave each kind of living thing that he studied a special name, which is called its scientific name. This name is

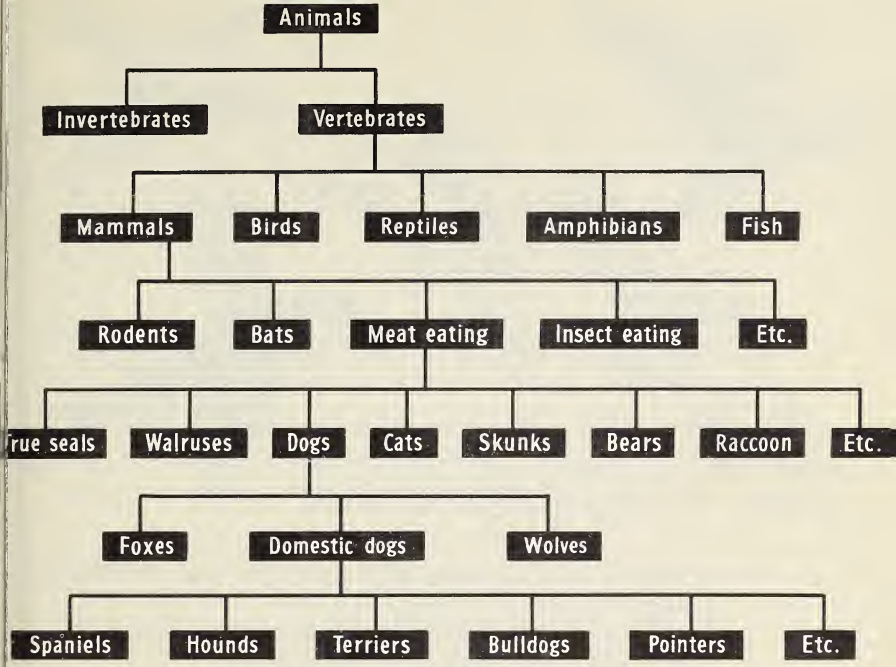
made up of two parts, just as your name is. For example, *Columba livia* is the scientific name for the common pigeon. *Quercus alba* is the scientific name for the white oak tree. Each part of the name is a Latin word or a word made to look like a Latin word.

Today scientists all over the world use a plan of classifying and naming living things that is based on the work of Linnaeus. Of course, changes have been made in his plan as new facts about animals and plants were discovered. However, living things are still classified according to their structure and given a scientific name. When a scientist in our country writes to a scientist in Mexico or France or Japan about some kind of animal or plant, he uses its scientific name. The other scientist knows exactly what kind of animal or plant is meant, because each kind of living thing has a scientific name of its own. No other animal or plant has a name just like it.

In this unit animals and plants are classified according to a plan very much like the one that scientists now use. Living things with the same characteristics of structure are grouped together. Each group has its own characteristics, and no other group is exactly like it. A large group can be divided into smaller groups. The smaller the group is, the more like one another the living things in the group are. You can see that this is true if you classify a dog according to its characteristics of structure.

You can easily tell that a dog is not a plant. So you put it in the big group of living things called animals. In this group there are more than 850,000 kinds of living things. However, you know that a dog has a backbone. It must belong in the smaller group of animals known as vertebrates. This group includes about 40,000 kinds, but you have learned that the vertebrates can be divided into five smaller groups: fish, amphibians, reptiles, birds, and mammals. A dog must be a mammal, because it has milk glands and hair on its body.

This is probably as far as you can go in classifying a dog. But there are about 4000 kinds of mammals. So a scientist goes still further. The mammals can be divided into nineteen smaller groups. After carefully studying the dog, the scientist decides that it belongs in the group of mammals that eat meat. Other mammals

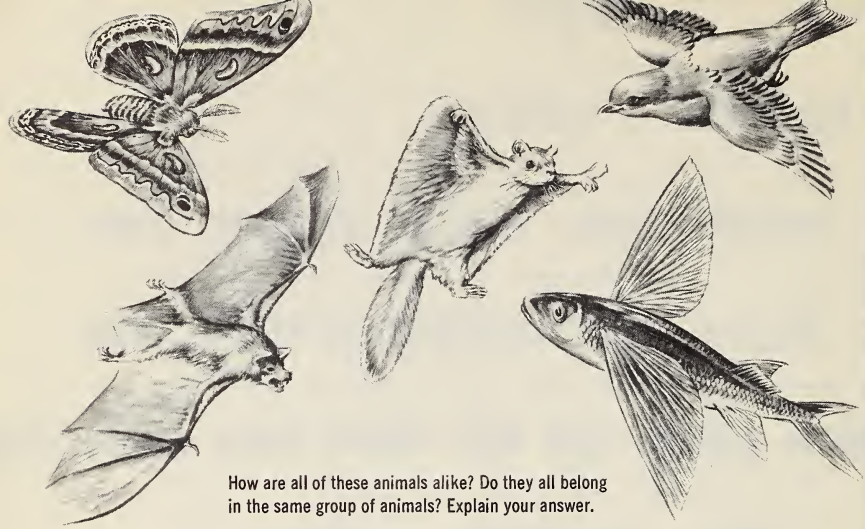


in this group are wolves, foxes, cats, lions, bears, raccoons, skunks, seals, and walruses. They all have teeth that are arranged in much the same way. The meat-eating mammals can be divided into eleven smaller groups. The dog is put in the group that also includes wolves and foxes. Then this group is divided into two smaller groups. The foxes are put in one group, and the wolves and the dog in the other.

Now the scientist has classified the dog, and he can give it a scientific name. He calls it *Canis familiaris,* which means the familiar, or common, dog. There are about 200 breeds of dogs, but each breed is more like all the rest than it is like any other kind of animal. So you can see that the smaller the group in which a living thing is put, the more nearly alike are the living things in the group.

SELF-TESTING EXERCISES

1 Explain why many of the plans for classifying living things did not work very well.



How are all of these animals alike? Do they all belong in the same group of animals? Explain your answer.

2 **a** What plan did Linnaeus use to classify and name animals and plants?

b Why was this a better plan than any that had been used before?

3 What plan of classification do scientists use today?

4 Using a dog as an example, explain how scientists classify a living thing and give it a scientific name.

PROBLEMS TO SOLVE

1 How does classifying animals and plants make it easier to learn about them?

2 Aristotle, the famous Greek thinker of long ago, worked out a plan for classifying animals. In one group, he put all the animals that gave birth to living young. In another group, he put all the animals that laid eggs. Do you think that this was a good plan of classification? Give reasons for your answer.

3 How would you go about the job of classifying a living thing that you had never seen before?

4 Work out a plan for classifying some things that you know such as the members of your class, the trees near your home, or the plants in your garden. State what characteristics you use for making the large groups and also what other characteristics you use for dividing the large groups into smaller groups.

5 How many examples of classifying things can you think of? Make a list and after each example state what characteristics are used to separate the things into groups. For example, the books in your school library are probably classified very carefully. Are they classified according to height, thickness, color, weight, subject, author's name, or what?

SUMMARY EXERCISES

1 Write down the big ideas that you learned in this unit. Be sure to use complete sentences.

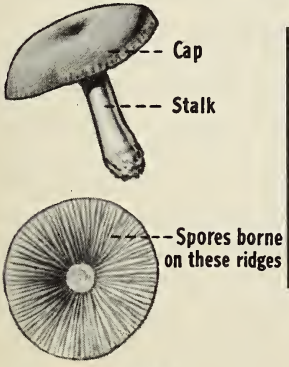
2 Show that you understand the meaning of the following words: classify, vertebrate, invertebrate, amphibian, appendage, arthropod, segment, arachnid, crustacean, mollusk, parasite, protozoan, algae.

ADDITIONAL ACTIVITIES

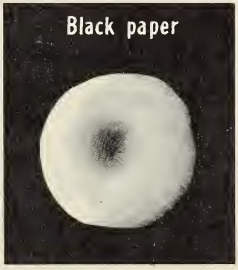
1 Keep an animal pet such as a rabbit, white rat, guinea pig, hamster, canary, turtle, frog, or goldfish. Provide the animal with a home and learn to feed and take care of it. Watch the animal to see how it lives.

2 Learn more about the skeletons of vertebrate animals. If mounted skeletons are available, use them for study. Otherwise, collect the bones of different vertebrates. Clean the bones thoroughly and fasten them together with wire to make complete skeletons.

You can make a spore print of a mushroom if you follow the directions given below.

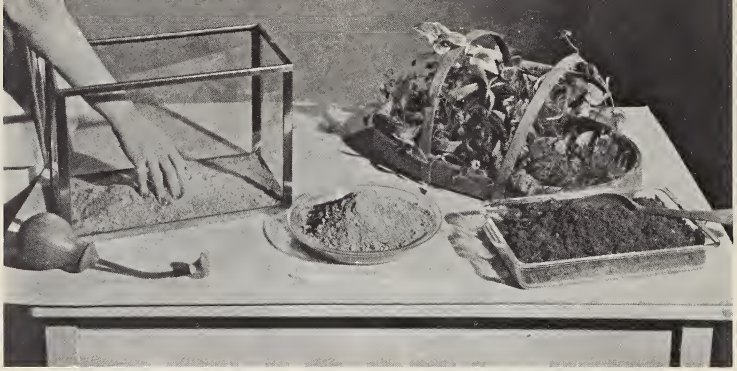


1 Cut off the stalk.



2 Put the cap on the paper, stalk side down. Cover with a dish.

3 Let this stand overnight and then remove.



To make a terrarium, you need clean sand, charcoal, good soil from a garden or greenhouse, small plants, and some moss if possible. Spread an inch or two of sand on the bottom. Then put a layer of chopped charcoal over the sand.

3 If you have a good magnifying glass or a microscope, examine the outer covering of different animals. Look at the hair and skin of mammals, the feathers and skin of birds, the skin of snakes and frogs, the scales of fish, and so on.

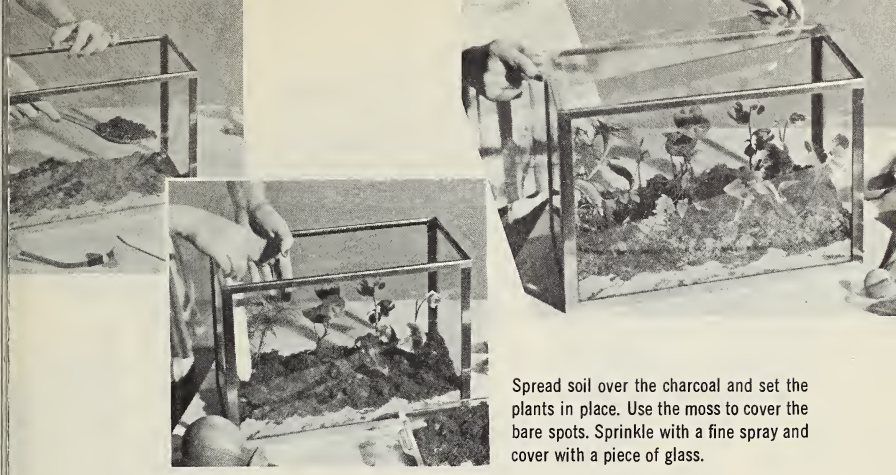
4 Set up an aquarium in which you can keep tadpoles, fish, water snails, clams, or crayfish. It can be made from any kind of glass tank or jar that will hold water. Green water plants can be grown in the aquarium if a layer of sand or soil is put on the bottom.

5 If you have a goldfish, watch to see how it breathes. Notice its mouth and gill covers as they open and close. Get a fish or a large fish's head from a market and examine the gills. Use scissors to cut off the gill cover and then study the gills.

6 Collect as many different kinds of arthropods as you can. You should be able to find insects of various kinds, spiders, crayfish, sow bugs, and centipedes. Examine each arthropod carefully, using a magnifying glass when you need it. Does each arthropod have all the characteristics of the group? What other characteristics does it have?

7 Get some large earthworms and put them in a pan lined with moist towel paper. Watch the worms carefully to learn all that you can about them. See what effect light and darkness have on the worms. Which do they prefer?

8 Examine some soil or mud with a magnifying glass to see whether you can find any roundworms. Also try to catch some flatworms by putting a piece of raw meat in a pond or stream.



Spread soil over the charcoal and set the plants in place. Use the moss to cover the bare spots. Sprinkle with a fine spray and cover with a piece of glass.

9 If you can get a microscope, use it to see protozoans and also to examine small algae and fungi. Protozoans can often be found in water in which dry leaves or grass have been left for a week or more. Pond scum contains algae. They can also be found on the damp north side of trees and old buildings. A small piece of yeast cake contains hundreds of tiny yeast plants.

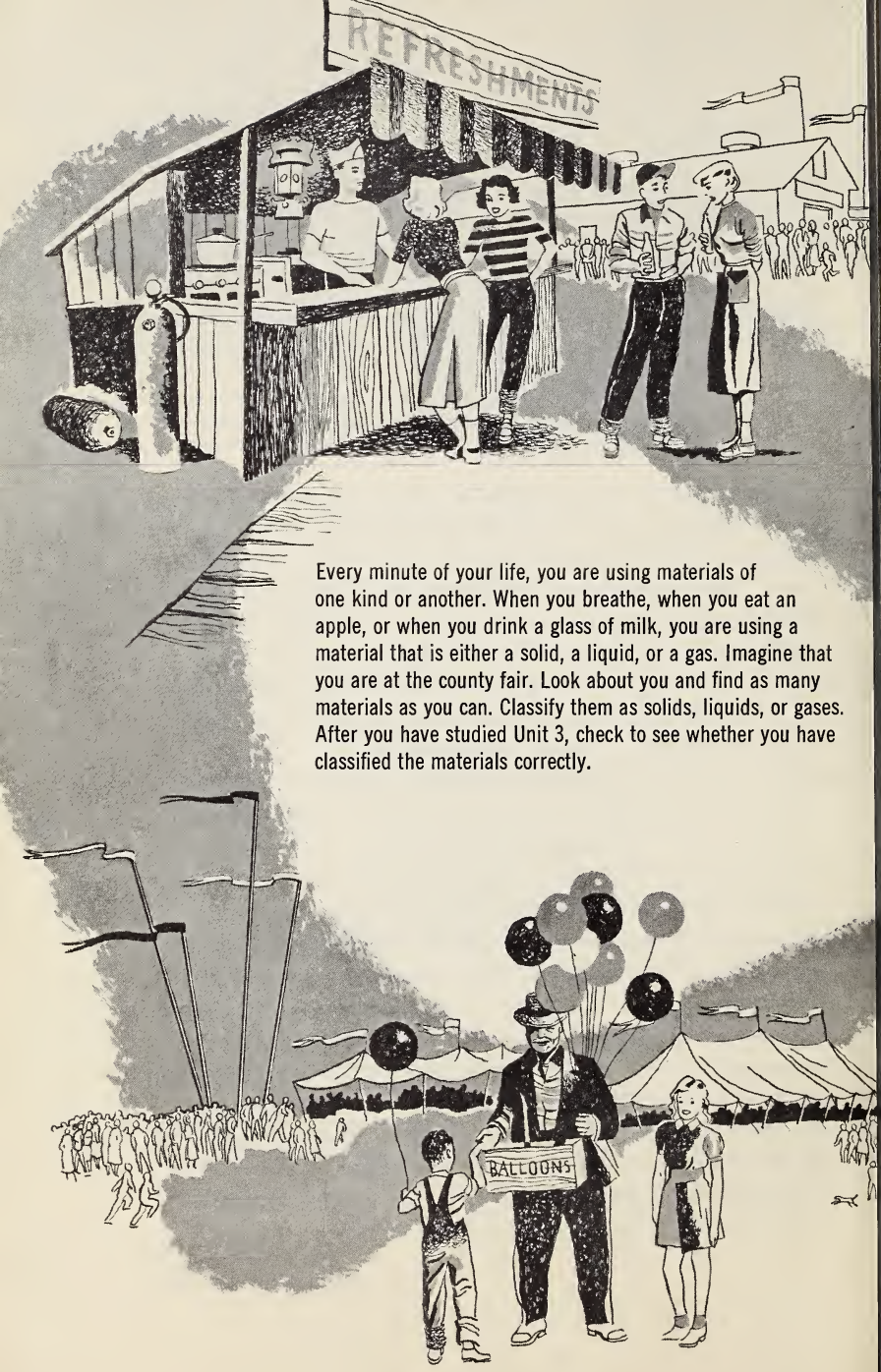
10 Soak some bean seeds and corn seeds in water for two days. Then remove the outer covering, or seed coat. Which kind of seeds easily separates into halves? Which kind does not?

11 Collect leaves and press them between the pages of old magazines until they are very dry. Then fasten them on sheets of paper in a notebook. Divide the leaves into two groups. In one group put those with veins that all run in the same direction. In the other group put those with veins that form a network.

12 Examine the leaves of ferns. How are they different from the leaves of seed plants? Can you find spore cases on the backs or edges of the leaflets?

13 With a magnifying glass, look carefully at a moss plant. Do you see the parts that look like tiny stems and leaves? Can you find the little holders for the spores?

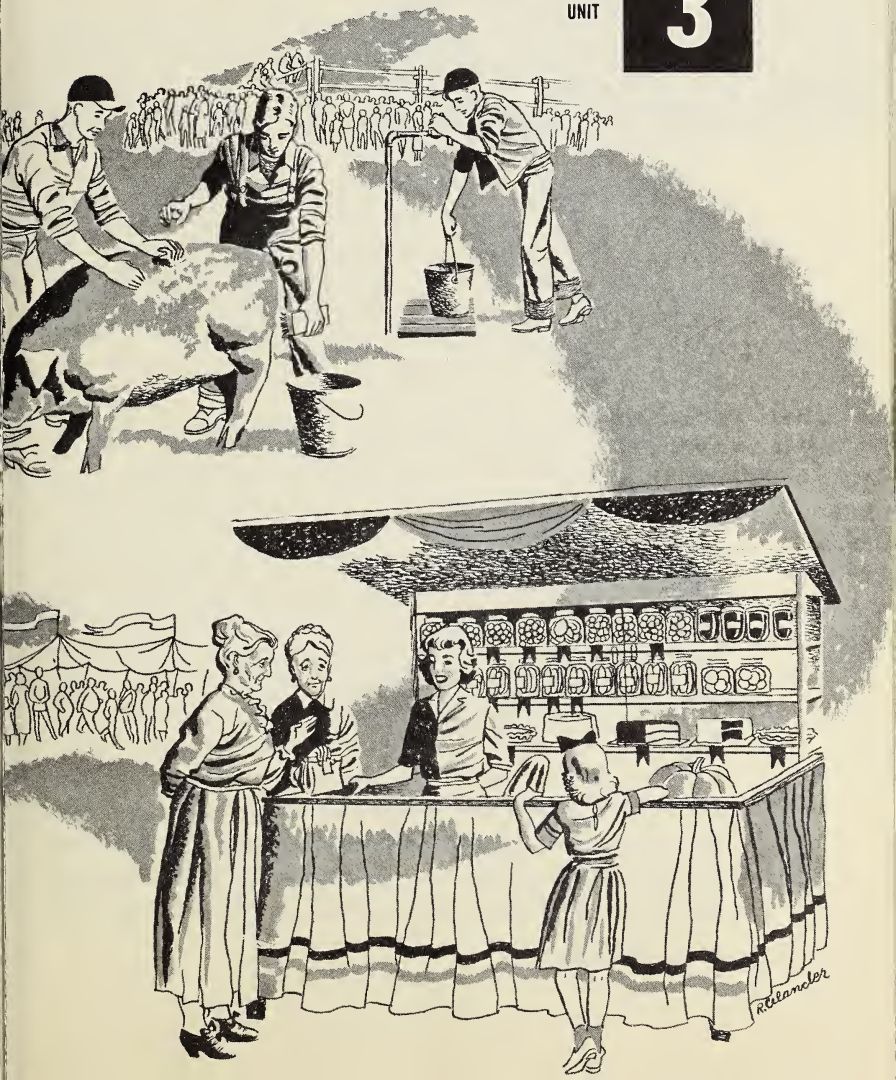
14 In reference books, read to learn more about each group of animals and plants that you studied in this unit. For example, find out what the different groups of mammals are called and what kinds of mammals belong in each group.



Every minute of your life, you are using materials of one kind or another. When you breathe, when you eat an apple, or when you drink a glass of milk, you are using a material that is either a solid, a liquid, or a gas. Imagine that you are at the county fair. Look about you and find as many materials as you can. Classify them as solids, liquids, or gases. After you have studied Unit 3, check to see whether you have classified the materials correctly.

What is a material?

UNIT 3



LOOKING AHEAD TO UNIT 3

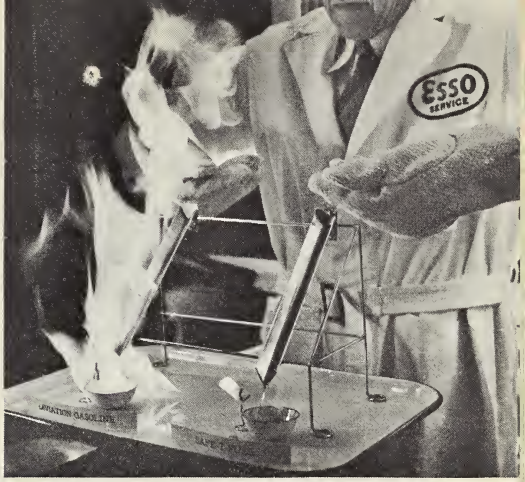
If you were asked to make a list of all the materials that we use, do you know how long it would take? If you wrote down ten materials every minute for eight hours a day, it would take you over three months to finish the list. There are more than 500,000 different materials, and new ones are being discovered all the time. We are made of materials. We work and play with materials. We eat materials. Every day we use such things as iron, wood, glass, rubber, cotton, wool, sugar, and water. The more we know about these materials, the better we can use them.

You already know that scientists called chemists spend their lives working with materials. Chemists want to find out what materials are made of, what happens to materials when they are heated, put into water, or mixed with certain chemicals. These scientists are interested in making new kinds of materials and in finding out how materials can be made more useful to people. This unit tells about some of the things scientists have learned by working with materials and thinking about them.

One of the interesting things that scientists have discovered is that all materials are alike in certain ways. For example, glass and paper are alike in some ways. They do not look alike, and they are not used for the same purposes. Yet they have certain characteristics that are the same. Even water is like glass and paper in some ways. Air, which you cannot see, also has some characteristics that all other materials have. When you study this unit, you will find out how all these materials are alike. You will also find answers to such questions as: How is a liquid such as water different from a solid such as wood? In what two ways are water and wood alike? Is air a material? What is a solution? How are materials put together?

1 How are all materials alike?

It is easy to tell the differences in materials. You know that wood, water, and air do not look alike. A block of wood is a solid material. If you set it on the table, it keeps its shape and it



Scientists have made a new material that helps prevent fires in airplanes. When poured past a flame, the safety gasoline on the right does not explode or burn as the regular gasoline on the left does.

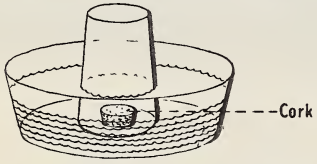
stays there. If you pour water on the table, it makes a puddle or runs off on the floor. It does not have any shape of its own. You cannot see air at all, and you cannot cut off a piece of air and put it on the table. But on a windy day you can feel air moving around you. You know, then, how wood, water, and air are different from one another. Can you think of how these materials are alike?

In order to understand clearly the first way that wood, water, and air are alike, let us suppose you have a box and some wooden blocks. You begin putting the blocks into the box. Finally, you cannot put any more blocks into the box. Why is this true? It is true because each block takes up a certain amount of room, or space. There is only a certain amount of space in the box. So the box will hold only a certain number of blocks. You can see, then, that wood takes up space. Water also takes up space. You know that a glass will hold only a certain amount of water. After the glass has been filled with water, no more water can be added.

It is easy to see that wood and water take up space, but what about air? Does it take up space, too? Let us see how two boys in a science class found out whether air takes up space. The teacher set three glasses on the table. She poured water into one glass and put soil in another. She put nothing in the third glass. Then she asked John to tell what was in each of the three glasses.

John answered quickly, "One has water in it, one has soil in it, but the third one is empty." Nearly everyone in the class thought that John was right. But Henry said, "I think each glass has something in it, and I can prove that it has." How do you suppose Henry showed the class that none of the glasses was empty? You can find out by doing Experiment 1.

Experiment 1 Does air take up space?



1 If air takes up space, what will happen when the glass is pushed about halfway into the water?

2 Push the glass into the water. What happens? Does the experiment show that air takes up space? Why?

3 How could you get water to go into the glass when it is pushed about halfway down? Try it and see. What happens? How does this help answer the question of the experiment?

Now you have seen that wood, water, and air are alike in one way. They all take up space. The amount of space that a material takes up is called its *volume*. There is another way in which all materials are alike. If you pick up a block of wood, you notice that it weighs something. Of course a small block of wood weighs very little, but a large wooden table may have more weight than you can lift. If you have ever carried a bucket of water, you know that water has weight. So you can see that wood and water are alike in a second way. They both have weight.

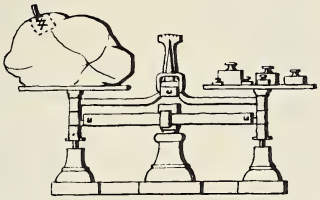
You cannot find out whether air has weight by lifting it with your hands. Air does not seem to weigh anything. To find out whether air has weight, you will need some plan for weighing air. You will need something to hold the air while you weigh it. You will also need a sensitive pair of scales or a balance. By following the directions for Experiment 2, you can find out whether air has weight.

Experiment **2** Does air have weight?

1 Balance the ball. Use small pieces of paper or tin foil, or use sand, to get an exact balance.

2 What should you do now to find out whether air has weight?

3 Do the experiment. What happens? Does this answer the question of the experiment?



4 What could you do now to check your results? Try it and see what happens. Does this show that air has weight? Why?

Careful experiments show that a cubic foot of air weighs about 1¼ ounces or .08 pound. The air in a medium-sized room weighs more than 100 pounds. You could not possibly lift all the air in your schoolroom.

Now you have learned the two characteristics of all materials: (1) They take up space, and (2) they have weight. Such things as light, heat, sound, and electric current are not materials. They do not take up space, and we cannot weigh them. Scientists have a special word they use for all materials to distinguish them from such things as light and heat. Scientists call all materials *matter*. All materials take up space and have weight. So we say that matter is anything that takes up space and has weight.

SELF-TESTING EXERCISES

1 Why do scientists study materials?

2 What effect does the scientists' work with materials have on the way we live? Give reasons for your answer.

3 **a** State two characteristics that all materials have.
b What special word do scientists use for all materials?

4 Why are such things as light and heat not materials?

5 **a** By doing an experiment, how could you show that air takes up space?
b By doing an experiment, how could you show that air has weight?

PROBLEMS TO SOLVE

1 Henry was trying to show that air takes up space. He found a bottle with a stopper to fit it. Then he made a hole through the stopper and put the stopper over the tubelike part of a glass funnel. Next he put the stopper in the neck of the bottle and poured some water into the funnel. Only a few drops ran into the bottle. The rest of the water just stood in the funnel. But when Henry lifted the funnel and stopper out of the bottle, the water all ran out of the funnel. Why would the water not run into the bottle when the stopper was in? Can you explain why the water ran through the funnel after Henry took the stopper out of the bottle? What did this experiment show?

2 Suppose there are two corked bottles that look exactly alike. You are told that one bottle contains air and that the air has been pumped out of the other bottle. How could you tell which bottle contains air? Explain your answer.

3 About how much does the air in your classroom weigh? (Multiply the length, width, and height of the room to find the volume in cubic feet. Then use the information given on page 83.)

2 How are solids, liquids, and gases different from one another?

So far you have learned two characteristics of matter. It takes up space and has weight. All materials are alike in those two ways. You know that wood, water, and air are alike because they are materials. But in some ways each is different from the

others. For one thing they look different. Now you are going to find out some other differences. We say that wood is a solid, water is a liquid, and air is a gas. Scientists call solids, liquids, and gases the three *states* of matter. State means a form that matter can have. But just what is a solid, and how does it differ from a liquid and a gas?

Bricks, chairs, and pencils are solids. They look different, but they have two characteristics that make them alike. A brick, a chair, or a pencil takes up the same amount of space in any part of a room. In other words, each has the same volume, no matter where you put it. A brick, a chair, or a pencil keeps its own shape wherever it is put. Any material that has a definite volume and a shape of its own is a solid. A material does not have to be hard or firm to be called a solid. A wet piece of clay or a piece of fresh bread is neither hard nor firm, yet each is in a solid state. Each has a definite volume and a shape of its own.

A liquid has one characteristic of a solid. It takes up a definite amount of space or has a definite volume. If you fill a glass with water, no more water can be added. However, a liquid is different from a solid in one way. If you pour water onto a table, the water will spread out over the top. If you pour water into a bottle, it will take the shape of the part of the bottle that it fills. If you pour water into a pan, it will take the shape of the part of the pan that it fills. A liquid has no shape of its own. It always takes the shape of the part of the container that it fills. Any material that has a definite volume but no shape of its own is a liquid.

What difference between a solid and a liquid is shown here? In what way are a solid and a liquid alike?

Roomful of air

No air

Bottle of air

If you open the bottle of air in the room containing no air, what happens? Make a drawing to show this. How is your drawing different from the room on the left?

A gas has neither of the characteristics of a solid, but it is like a liquid in one way. It has no shape of its own. It takes the shape of the container that it fills. The air in a glass takes the shape of the glass. However, a gas is different from a liquid in one way. To understand this difference, suppose that you have a room from which all the air has been pumped. In this room you put a tightly corked bottle of air. The only air in the room is in the bottle. Now suppose you remove the cork from the bottle. What do you think will happen to the air in the bottle? Scientists know that the air in the bottle will spread out until there is some air in every part of the room. So a gas does not take up a definite amount of space. Any material that has no shape of its own and no definite volume is a gas.

You have seen many solids and liquids, but you probably have seen very few gases because most of them are colorless. Air is a mixture of colorless gases. It is made up of nitrogen, oxygen, carbon dioxide, and other gases. Although you cannot see most gases, you can smell some of them. You can smell the gas that is used in stoves for cooking and heating. Many gases can be neither seen nor smelled. You cannot see or smell the gases in air. If an automobile engine is left running in a closed garage, the garage fills with a poisonous gas called carbon monoxide. You cannot see or smell this gas, but it can quickly kill you.

SELF-TESTING EXERCISES

1 List the three states of matter. Then tell which of the following characteristics belong to each state of matter: **a** Has a definite volume. **b** Has a shape of its own. **c** Has no shape of its own. **d** Takes the shape of the part of the container that it fills. **e** Fills any container into which it is put. **f** Has no definite volume.

2 **a** In what way is a liquid different from a solid?
b In what way is a gas different from a liquid?
c In what two ways is a gas different from a solid?

3 In which of the three states of matter, solid, liquid, or gas, does each of the following materials usually belong? Iron, glass, milk, honey, air, paper, sponge, oil, vinegar, oxygen.

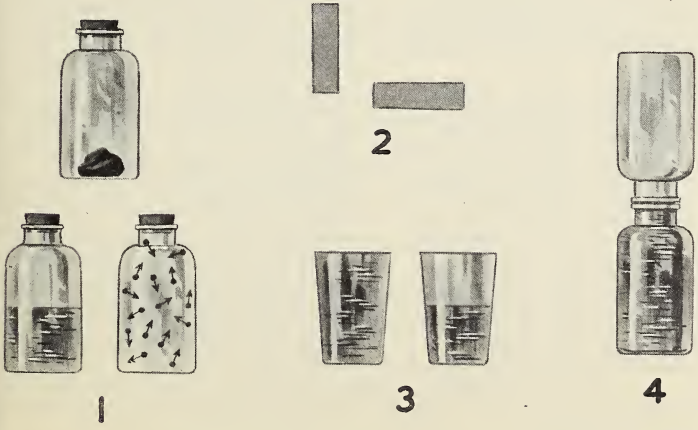
PROBLEMS TO SOLVE

1 Picture 1 represents the three states of matter. What two characteristics of each state can you see?

2 What state of matter is shown in Picture 2? How do you know?

3 In Picture 3, there are two glasses with water in them. Can you pour all the water from either glass into the other? What characteristic of water does this show?

4 In Picture 4, is the material in the lower bottle a liquid or a gas? Explain your answer.



3 What is a solution?

How are all solutions alike? You know that a material is a solid, a liquid, or a gas. And you have learned that solids, liquids, and gases are the three states of matter. You have also learned how each state of matter is different from the others. However, very often we mix a material in one state with a material in another state. A *solution* is a mixture made in this way.

Solutions are so important to you that you could not stay alive without them. You cannot use the air you breathe or the food you eat until they are in your blood in the form of solutions. Every time you put sugar in lemonade or cocoa, you are making a solution. Perhaps you have helped spray plants or fruit trees to keep them from being eaten by insects. If you have, you were probably using a solution. You have heard about solutions and used solutions. Now do Experiment 3 to find out what a solution is.

Experiment **3** What are the characteristics of a solution?

What you need: Teaspoon; tea leaves; three glasses (or beakers); hot water; three 6-inch circles of filter paper (or towel paper); funnel; three test tubes; sugar; copper sulphate.

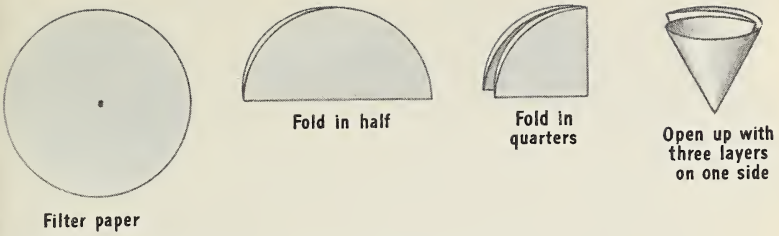
What you do: Put a teaspoonful of tea leaves in a glass and pour hot water over them. Watch what happens. Does the water change color all at once? Or does the color slowly spread through the water?

Now fold a circle of filter paper as shown in the picture on page 89. Line a funnel with the folded filter paper. Wet the paper with clear water to make it stay in the funnel. Set the funnel in a test tube. Carefully pour some of the tea solution into the funnel. Be sure that no material gets through the funnel without going through the filter paper.

Examine the filtered liquid in the test tube. Is it still colored? Or did the colored material stay on the filter paper? Taste the filtered liquid. Is there tea in it? Hold the test tube up to the light. Is the tea solution in the test tube clear or cloudy? Can you see any particles of tea floating in it?

Let the test tube of tea solution stand for several days. Does it stay the same color? Or does the colored material from the tea settle to the bottom? Taste the solution by taking a little liquid from the top. Can you still taste the tea? Now write down the three characteristics of the tea solution.

Then make two more solutions to see whether they have the same three characteristics as the tea solution. Use a teaspoonful of sugar for one solution and a teaspoonful of copper sulphate for the other. Do with each solution what you did with the tea. BUT DO NOT TASTE THE COPPER SULPHATE SOLUTION. IT IS POISONOUS. Then answer the same questions about these two solutions that you did for the tea solution. In what three ways are all of the solutions alike?



Follow these directions when you fold the filter paper for Experiment 3.

When you poured hot water over the tea leaves, you saw the color from the tea slowly spread throughout the container. When you passed the tea through the filter paper, you found that only the tea leaves were removed. The color and the taste of the tea remained. The color was clear when you held it up to the light. If you let the tea stand, you saw that the color stayed in the water. It did not settle to the bottom. The taste was still the same all through the solution.

Now you can understand the three characteristics of a solution. First, the liquid in a solution is clear. Even with a powerful microscope, you cannot see particles of the solid floating in the liquid. When a solid dissolves in a liquid, the solid disappears. Solutions such as ocean water and well water both contain dissolved materials, but the solutions are clear. Red ink is a solution, and it is also clear. You cannot see particles of a red solid floating in the liquid.

A second characteristic of a solution is that the dissolved material will pass through any filter that the liquid can go through. You cannot remove the dissolved materials by filtering the solution. No matter how fine a filter you use, you cannot filter the salt out of ocean water.

A third characteristic of solutions is that dissolved materials are spread evenly through all parts of the solution. The dissolved material in a solution does not rise to the top or sink to the bottom, no matter how long the solution stands. Sometimes you see solutions in which crystals of the dissolved solid have formed on the

sides or bottom of the container. This is what has happened. The water can dissolve only a certain amount of the solid. Some of the water may then change to a gas, or evaporate. If the water that is left cannot hold all of the dissolved solid, then crystals will form. But the solid that is still dissolved is evenly spread all through the water that is left.

Many liquids appear to be solutions, but they do not have all the characteristics of solutions. If you let milk stand for a while, the cream will separate from the rest of the milk, and rise to the top. Many hand lotions, hair tonics, and metal polishes must be shaken before they are used. They are not solutions because the parts of the mixture separate when they are allowed to stand. This special kind of mixture is called a *suspension.* In a suspension, the small particles of a solid remain *suspended,* or spread throughout the liquid, without dissolving. The particles of the solid may rise to the top or sink to the bottom after the mixture has been left standing for a while. If you do Experiment 4, you can find out whether a mixture of starch and water forms a solution or a suspension.

Experiment 4 Is a mixture of starch and water a solution or a suspension?

What you need: Teaspoon; starch; two glasses (or beakers); cold water; tincture of iodine; medicine dropper; two test tubes; 6-inch circle of filter paper (or towel paper); glass funnel.

What you do: Put a teaspoonful of starch in a glass of cold water and stir the mixture thoroughly. Is the mixture clear or cloudy?

Now make a dilute solution of tincture of iodine by adding six medicine droppers full of the iodine to half a glass of cold water. Pour a little of the starch mixture into a test tube and add a drop of the dilute iodine solution. The mixture will turn blue or blue-black. Starch is the only material that gives this color with iodine. So iodine is a test for starch.

Fold a filter paper and put it in the glass funnel as you did in Experiment 3. Set the funnel in a test tube. Then pour some of the starch mixture that was not tested with iodine into the funnel. Add a drop of iodine solution to the filtered liquid in the test tube. Did the starch go through the filter paper? How do you know?

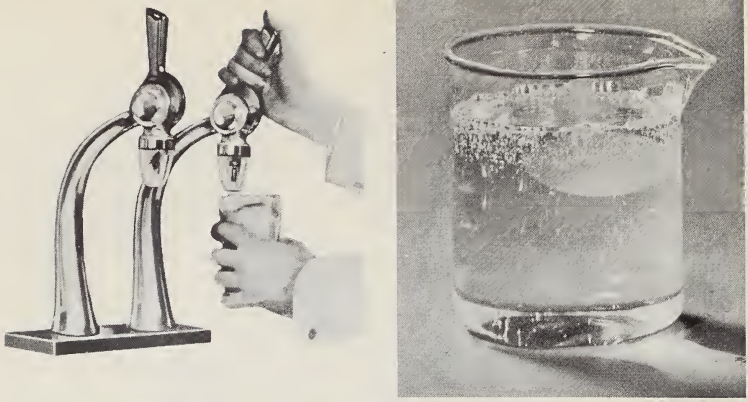
Let some of the unfiltered starch mixture stand for several days. Does the starch settle? Is the mixture of starch and water a solution or a suspension? Give three reasons.

Oil is not soluble in water, but it forms a layer on top of the water. So scientists can control mosquitoes by pouring oil on the water where they grow. The mosquito larvae die because the oil keeps them from getting to the surface for air.

When a material can dissolve in a certain liquid, we say that the material is *soluble* (sol'ū bəl) in that liquid. Sugar is soluble in water. On the other hand, a material that cannot be dissolved in a certain liquid is said to be *insoluble* in that liquid. Starch is insoluble in water. Some materials may be insoluble in one liquid but soluble in some other liquid. In most suspensions, the material mixed with the liquid is insoluble in that liquid.

You have seen that some solids can dissolve in liquids. Can liquids dissolve in liquids? Alcohol is a liquid. We can mix it with water, and it will form a solution. Acetic acid is a liquid, and it will form a solution with water. We call the solution vinegar. Oil is also a liquid, but it is not soluble in water. So we cannot say that every liquid will dissolve in another liquid. However, oil will form a solution with gasoline. So we can say that some liquids can dissolve in other liquids, but not all liquids can dissolve in every liquid.

If solids and liquids can dissolve in liquids, you will also want to know whether gases can dissolve in liquids. A few years ago, the people in a certain part of Illinois began to notice a strange taste in their drinking water. The water came from wells. Scientists were asked to find out why the water had this strange taste.



Pressure keeps carbon-dioxide gas dissolved in soda water. When the faucet is opened, the soda water is forced out and the pressure is released. The gas comes out of the solution and makes your drink bubble and fizz. You can see bubbles of carbon dioxide rising to the top of the water in the glass on the right.

This is what they discovered. For some reason, a gas had formed down in the earth. The gas had slowly worked its way through the soil and into the wells, where it dissolved in the water. The dissolved gas gave the water a strange taste.

Gases, then, can dissolve in liquids. You have seen some dissolved gas come out of liquids. When you heat water, little bubbles form on the bottom and sides of the pan. These are bubbles of air that have been dissolved in the water. When you open a bottle of "pop," you see bubbles of carbon-dioxide gas rise to the top. This dissolved carbon-dioxide gas gives the drink its sharp, stinging taste. Some of the gas comes out of the liquid when the bottle is opened, because the gas was forced into the liquid under pressure. When you open the bottle, there is no longer enough pressure to keep all the gas dissolved in the liquid.

SELF-TESTING EXERCISES

1 What three characteristics do all solutions have?
2 What do we mean when we say that a material is soluble in a certain liquid?
3 Explain the difference between a solution and a suspension.
4 Give two examples of a gas dissolved in a liquid.
5 If you are planning to make a solution of a solid in a liquid, what should you know before you start?

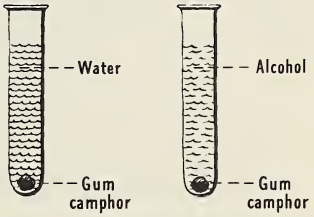
WHY DO WE USE DIFFERENT LIQUIDS TO MAKE SOLUTIONS? Have you ever tried to get wet paint off your hands with water? If you have, you know that it does not work. But when you use some turpentine, gasoline, or kerosene, the paint disappears like magic. Why do you suppose these liquids remove the paint, while water does not remove it? The reason should not be hard to discover. The oil in the paint is insoluble in water, but it is soluble in certain other liquids such as turpentine, gasoline, and kerosene. Do Experiment 5 to find out how to dissolve materials that are insoluble in water.

Experiment **5** How can we dissolve materials that are insoluble in water?

1 Cork the test tubes and shake them. Then let them stand overnight.

2 What happens in each test tube? Which liquid dissolves gum camphor?

3 How could you find out whether water, alcohol, or carbon tetrachloride will dissolve lard or butter? Do the experiment. What do you discover?



4 How can you use what you learned in this experiment?

Water is the greatest dissolver in the world. Water dissolves more kinds of materials than any other liquid. Yet you have learned that there are many materials that it does not dissolve. Water does not dissolve gum camphor, but alcohol does. Water does not dissolve grease from clothing, but carbon tetrachloride does. We call water, alcohol, and carbon tetrachloride *solvents,* because they can dissolve other materials. Chemists have spent much time in discovering what liquids are good solvents for each material they want to dissolve. Rubber cement could not be made until someone discovered a liquid in which rubber is soluble. There was no iodine for cuts and scratches until someone dis-

covered a liquid in which the hard iodine crystals are soluble. We would have a hard time removing stains from our clothing if we did not know what solvents to use for the materials in the stains. To remove a stain, you must first know what kind of stain it is. Then you must know what solvent to use. The table below tells what solvents to use in removing some common stains.

How to dissolve common spots and stains

Spot or Stain	Solvent	Spot or Stain	Solvent
Adhesive tape	Carbon tetrachloride	Grass stains	Ether or alcohol or soap and alcohol
Blood	Solution of salt, soap, and cold water	Grease	Carbon tetrachloride
Candy, molasses, or syrup	Water, preferably hot	Iodine	Sodium thiosulphate or alcohol
Chewing gum	Carbon tetrachloride	Paint	Turpentine or carbon tetrachloride
Chocolate, cocoa, coffee, or tea	Boiling water	Shellac	Alcohol
Fruit stains	Boiling water	Tar	Carbon tetrachloride

SELF-TESTING EXERCISES

1 Name three liquids in which paint is soluble.
2 What is a solvent?
3 What two things must you know before you can remove a stain?
4 Why is a camphor solution made with alcohol instead of water?

PROBLEMS TO SOLVE

1 The water in the ocean is salty. Explain why a layer of salt does not settle on the bottom of the ocean.
2 Make a list of some solutions that are used in your home. Tell what each solution is used for.
3 What is likely to be one difference between rain water and well water?
4 Suppose that you were given a bottle that has a solid and a liquid mixed in it. How could you tell whether the solid has dissolved to form a solution? What observations would you make and what experiments could you do to find out?

People use many solvents in their work. Painters remove old paint by putting on a solvent that softens the paint. Then the paint can be scraped off. When a painting job is done, a careful painter cleans his brush with a solvent.

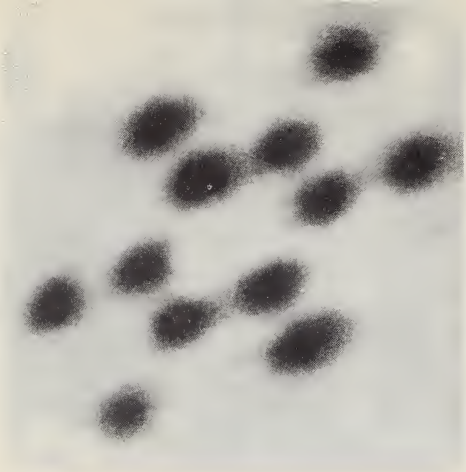
5 If you have grease on your hands, why is it better to wash them with kerosene before using soap and water?

6 Hard water contains dissolved minerals. Could you soften hard water by filtering out the minerals? Explain your answer.

4 How are materials put together?

WHAT IS THE MOLECULAR THEORY? You have found out some facts about materials. You have learned that all materials take up space and have weight. A material may be in the form of a solid, a liquid, or a gas. Solids, liquids, and gases can dissolve in liquids to make solutions. Solids hold their shapes, but liquids and gases change to fit the shapes of their containers. How are liquids and gases different from solids so that they can do this? A liquid fills only a certain amount of space, but a gas fills any amount of space it can get into. How can a gas get larger or smaller to fit any size bottle or room? To answer these questions, you must understand how materials are put together.

When you see something that raises a question in your mind, you often work out some explanation. You may keep thinking



By taking a special kind of X-ray picture, scientists can see the pattern made by the atoms in a molecule. This picture shows the carbon atoms in a molecule that has been magnified 200 million times!

about your problem and your explanation of it. You find other facts that fit your explanation. Finally, you decide that your explanation must be true. But you cannot prove it. An explanation that seems to be true, but is not absolutely certain, is a *theory*.

Scientists use many theories in their work. They consider a theory good only so long as it fits the facts it should fit. If someone discovers a fact that the theory cannot explain, the theory must be changed. However, a theory may still be called a theory even after everyone believes that it is correct. This is true of the *molecular* (mə lek′ū lər) theory, which explains how materials are put together.

Scientists believe that all kinds of matter are made up of very small particles called *molecules* (mol′i kūlz). That is why this theory is called the molecular theory of matter. Molecules are so small that they cannot be seen with an ordinary microscope. But scientists have seen some of the largest molecules with the new electron microscope. This microscope makes things look 200,000 times larger.

It is hard to realize how small molecules must be. One scientist has said, "If a drop of water were magnified until it was as big as the earth, the molecules would be only as big as baseballs." There are about as many molecules in a thimbleful of water as there are sand grains in two and one-half cubic miles of sand. In one breath, a person takes about 108,000,000,000,000,000,000,000

molecules of air into his lungs. If the molecules in a pint jar of air were allowed to escape at the rate of 10 million a second, it would take 40 million years to empty the jar. These numbers are quite impossible for you to imagine. But if you realize that the smallest bit of material you can see with your naked eyes contains millions of molecules, you will have some idea of how small molecules must be.

Not only are molecules smaller than you can probably imagine, but scientists believe that molecules are separated from one another by spaces. As you might expect, the spaces between the molecules of a liquid are usually larger than those between the molecules of a solid. The spaces between the molecules of a gas are larger than those between the molecules of a liquid. It may be hard to believe that materials such as gold or iron really have spaces in them. Mercury is the silver-colored liquid used in many thermometers. If a piece of gold is put in a dish of mercury, chemists have discovered that the mercury will go into the gold. There must be spaces between the gold molecules into which the mercury molecules can go.

Besides believing that there are spaces between all molecules, scientists believe that molecules are always moving. It is easy to think of the molecules of liquids and gases as always moving. It is harder to realize that the molecules of a solid, such as silver, are moving. However, when a brass spoon is covered with silver, chemists find that a small amount of the silver makes its way into the brass. The molecules of silver must have moved into the spaces

The molecules of a solid are usually closer together than those of a liquid. The molecules of a liquid are closer together than those of a gas.

between the molecules in the brass. In a gas or liquid, the molecules seem to bounce about freely in all directions. In a solid, they seem to move back and forth close to the same place.

Now you have learned three ideas of the molecular theory: (1) All matter is made up of small particles called molecules. (2) There are spaces between molecules. (3) The molecules are always moving. With these ideas you should be able to understand some of the things you have noticed about materials and what they do.

SELF-TESTING EXERCISES

1 Why do scientists think up theories?
2 How is a theory different from a fact?
3 What is the molecular theory?

WHAT OBSERVATIONS CAN BE EXPLAINED BY THE MOLECULAR THEORY? Scientists use the molecular theory in many ways to explain how matter acts. In Experiments 1 and 2, you observed the two characteristics of matter. By using the molecular theory, you can explain why matter has these characteristics. Matter is made up of molecules that take up space and have weight. The molecular theory also explains the differences between states of matter. The molecules in a solid are close together and move back and forth near the same spot. So a solid has a definite volume and a shape of its own. In a liquid, the molecules are close enough together so that a liquid takes up a certain amount of space. Because the molecules in a liquid move more freely than those in a solid, a liquid has no shape of its own. The molecules of a gas are farther apart and move about so freely that a gas has no definite volume and no shape of its own.

By using the molecular theory, you can explain what happens when something dissolves. In Experiment 3, you put copper sulphate into a glass of water. As you watched, a blue color appeared in the water around the copper sulphate. If you let the liquid stand, you saw the blue color spread very slowly through the water. At the same time the copper sulphate disappeared. What

What does Picture 1 show? What does Picture 2 show? How can you explain what is happening in Picture 3?

was happening to the copper sulphate? When the copper sulphate was put into water, molecules of the copper sulphate must have gone into the spaces between the molecules of water. The copper-sulphate molecules kept bouncing about among the water molecules and got farther and farther apart. Molecules kept leaving the copper sulphate until it was all dissolved. Then you could see no solid particles in the solution.

The explanation of how the copper sulphate dissolved in water seems to fit all solutions. The molecules of the solid move in between the molecules of the liquid and spread to every part of the liquid. The molecules of the dissolved solid are bouncing about rapidly. The molecules of water are also bouncing about. They all mix together and stay that way.

The molecular theory also explains what you observed in Experiment 4. A suspended material cannot pass through a filter as a dissolved material can. The particles of a dissolved solid are separate molecules. These molecules are so tiny that they can pass through any holes that the water molecules can pass through. In a suspension, such as starch, the particles of solid are thousands of times larger than the water molecules. Starch in water does not dissolve, or break apart into separate molecules. It remains in particles that probably contain thousands of molecules. These particles cannot pass through the filter as the water molecules can.

Many reservoirs for water-supply systems have settling basins, where the water stands for a while before it is used. After a time, the basins must be cleaned. Why? Was the material dissolved or suspended in the water? How do you know?

SELF-TESTING EXERCISES

1 Explain what happens when a solid dissolves in a liquid. Be sure to use the molecular theory in your explanation.
2 Use the molecular theory to explain the difference between a solution and a suspension.
3 How does the molecular theory explain the differences between a solid and a liquid? Between a liquid and a gas?

PROBLEMS TO SOLVE

1 If a lump of sugar is added to a cup of coffee, the coffee soon becomes sweet in all parts of the cup. Explain.
2 Two materials cannot take up the same space at one time. When you make a solution of sugar and water, are the sugar and water not in the same space? Explain your answer, using the molecular theory.
3 If the hole in the bottom of an ordinary flowerpot is sealed with wax and the pot is filled with water, the outside of the pot soon becomes moist. Explain how the water can get through the pot.
4 If a burner on a gas stove is opened and left unlighted, in a very short time you can smell the gas in all parts of the room. Why?

5 Using the molecular theory, explain why it is possible to force more air into a tire that has already been pumped up.

SUMMARY EXERCISES

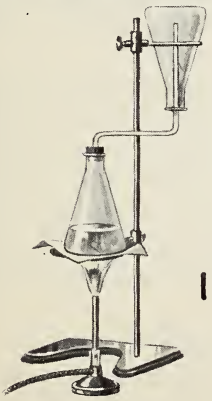
1 Think back over the unit and then write the answers to the following questions: How are all materials alike? How are solids, liquids, and gases different from one another? What is a solution? How are materials put together?

2 Show that you understand what the following words mean: volume, matter, state, solution, suspension, soluble, insoluble, solvent, theory, molecule.

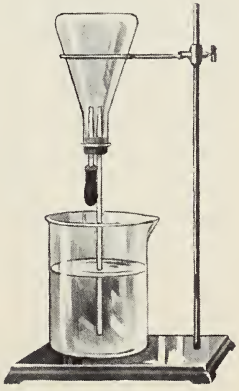
ADDITIONAL ACTIVITIES

1 Arrange an apparatus as shown in Picture 1 below. Heat the ammonia solution in the flask slowly until it begins to boil. The bottle will then be filled with almost pure ammonia gas. Keep the mouth of the bottle downward and set it in a pan of cool water. What becomes of the ammonia?

2 Make an ammonia fountain. Prepare a bottle or flask full of ammonia as in Activity 1, but close the mouth with a rubber stopper arranged as shown in Picture 2. Place the end of the tube in a glass of water and squeeze water from the medicine dropper into the flask. Explain what happens.



1



2

The right side of the glass windshield has been sprayed with a waxlike material. Why does water not stick to it? Paint is being sprayed from a can onto the radiator. A special liquid in the can changes to a gas when it is allowed to escape. How does the gas make the paint form a fine spray?

3 Make a crystal basket. First, make a small basket of cotton-covered copper wire and small string or thread. Make it small enough to go inside a larger beaker. Make enough hot solution of copper sulphate to cover the basket. Keep adding copper sulphate to the solution until it is very strong. Lower the basket into the solution and allow the solution to cool slowly.

4 Make some lemon soda water. Get a clean pint bottle with a screw top or some other kind of top that can be held on against considerable pressure from the inside. Put one teaspoonful of baking soda in the bottle and fill it half full of cold water. Now pour in four teaspoonfuls of lemon juice and fasten the top on quickly. Watch what happens. When the action in the bottle has stopped, pour some of the water into a glass and see what happens. What kind of solution did you make?

5 Find out what is the difference between a liquid and a fluid.

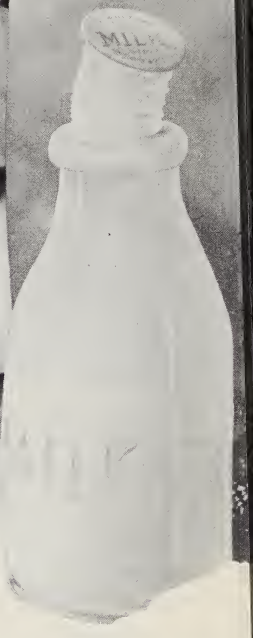
6 Get nine pieces of cloth of the same kind and divide them into sets of three. On one piece of each set, crush green grass or leaves and

What do these pictures show? How should the picture on the right look if you pumped in more air? Why?

rub them in hard. On the second piece of each set, rub in motor oil and then soot or dirt. Rub in wet paint on the third piece of each set. Then try to get the spots out of one set by washing it in clear water, out of the second set with soap and water, and out of the third with the solvent indicated for each stain in the table on page 94.

7 You can do another experiment to show the difference between a solution and a suspension. Fill a drinking glass with sugar solution. Then heat a teaspoonful of starch and a half cup of water in a small pan until it makes a clear paste. Stir the mixture while you are heating it so it will not burn or get lumpy. Add a small amount of the paste to a glass of water. Set the two glasses close together. With a flashlight, shine a beam of light through first one glass, then the other. Can you see any difference in the appearance of the light beam in the two liquids? What does this difference show?

8 In reference books, read about the following topics: matter; solutions and suspensions; molecules; solvents.



How do heating and cooling change materials?

arnold w. ryan

In each of the pictures on these pages, something has happened to a material because heating and cooling can change materials. What changes do you think have taken place? Can you explain any of these changes? As you study Unit 4 to find out how heating and cooling change materials, look at the pictures again and explain what you see.

LOOKING AHEAD TO UNIT 4

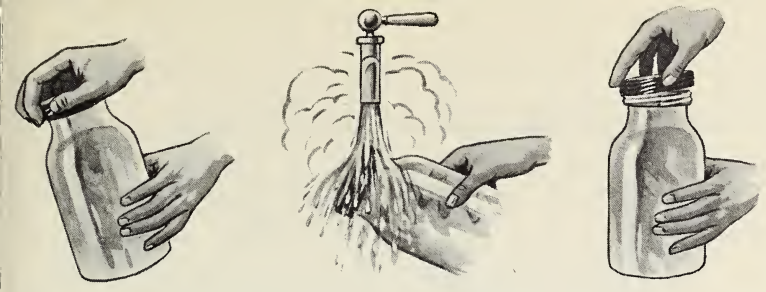
Have you ever tried to separate two glasses that were stuck together, one inside the other? Perhaps your mother told you what to do to get the glasses apart. She may have told you to put cold water in the inside glass and then to pour hot water on the outside glass. If you did this, you found that the glasses came apart easily. Can you explain why the glasses came apart? Can you explain what is happening in the pictures on the next page?

You may have had this experience, too. Betty's mother told her to heat some water on the stove. Betty filled a kettle with water, set it on the stove, and then went into the other room to read. After a while, she heard a sputtering noise in the kitchen. Much to her surprise, Betty found that the water was running over the edge of the kettle. It seemed that there was more water in the kettle than there was when Betty put it on the stove. What do you suppose had happened to the water in the kettle?

If you have taken an automobile trip on a hot summer day, you may have seen your father stop the car and let some air out of the tires. On a very cold morning in winter, he may have had more air put into the tires because they had become soft overnight. Can you explain this? Do you know what happened to the air in the tires?

You have often noticed that after a rain the little puddles of water on the streets and sidewalks usually disappear in a few hours. Did you ever wonder what becomes of the water? Do you remember the last time you had a drink of ice water? You did not spill the water, yet the cold glass was dripping wet. Where did the water on the outside of the glass come from? Why did it get on a cold glass but not on a warm one? To answer these questions, you must know how heating and cooling change materials.

As you study this unit, you will also find answers to such questions as: Do all materials change in volume when they are heated and cooled? How are solids changed to liquids? How are materials changed to gases? How are gases changed to liquids? How are liquids changed to solids? How do heating and cooling change the action of molecules?

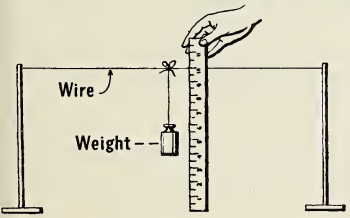


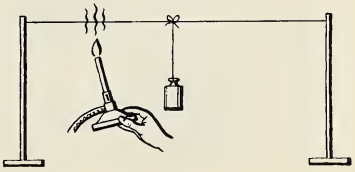
1

How do heating and cooling change the volume of materials?

DO ALL MATERIALS CHANGE IN VOLUME WHEN THEY ARE HEATED AND COOLED? You have learned that scientists call solids, liquids, and gases the three states of matter. You know that all matter takes up space and has weight. Solids and liquids take up a definite amount of space or have a definite volume, but gases have no definite volume. A gas fills any amount of space it can get into. The next three experiments will show you how heating and cooling change the volume of a solid, a liquid, and a gas.

Experiment 1 How do heating and cooling change the length of a wire?





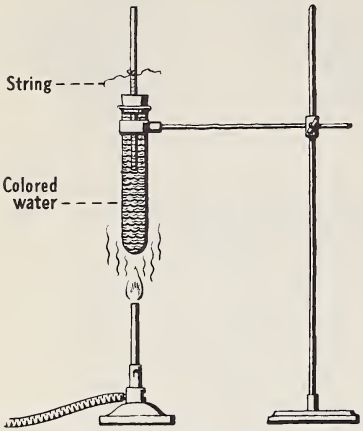
1 Use a ruler to show the distance of the weight from the table. Why must you do this?

2 Heat the wire along its whole length by moving the burner back and forth. What do you think will happen if the wire gets longer?

3 What happens when the wire is heated? What does this show?

4 What can you do now to find out how cooling changes the wire? Try it and see what happens. What does this show?

Experiment **2** How do heating and cooling change the volume of water?



1 Where is the string tied around the tube? Why must you do this?

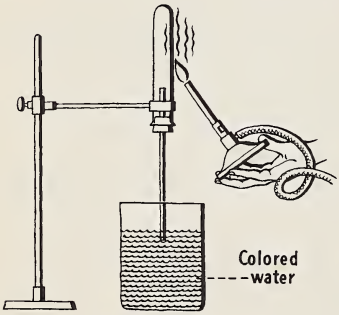
2 What do you think will happen if the volume changes when the water is heated?

3 Heat the water gently. What happens? What does this show?

4 What do you think will happen if the water is now cooled?

5 How can you do an experiment to test your idea? Do the experiment. What happens? Is your idea right or wrong?

Experiment **3** How do heating and cooling change the volume of air?



1 What do you need to do this experiment?

2 What does the picture tell you to do? What do you think will happen?

3 Do the experiment. What happens? How does this show you whether air expands when it is heated?

4 If you let the test tube cool, what do you think will happen? Try it. What does this show?

In the experiments that you just did, you tested the effects of heating and cooling on a solid, a liquid, and a gas. In each experiment you found that the material took up more space when heated and less space when cooled. When a material gets larger and takes up more space, we say that it expands. When a material

gets smaller and takes up less space, we say that it contracts. Some solids expand and contract so little that you would need special instruments to see that they do. In Experiment 1, you could see that the wire got longer when it was heated. Scientists know that it also got bigger around.

Could you now say that all solids, liquids, and gases expand when heated and contract when cooled? A scientist would not say this until he had done many more experiments. He would test many different solids, liquids, and gases to see whether they acted in the same way. From the results of just one experiment or a few experiments, it is not good thinking to say that all materials expand when heated and contract when cooled.

Scientists have done a great many experiments with different materials. The results of these experiments show that almost all materials take up more space when heated and less space when cooled. It is a *principle of science* that most materials expand when heated and contract when cooled. A principle of science is a statement that tells what usually happens under certain conditions. After scientists had experimented with many materials to see whether all of them changed in volume when heated and cooled, the scientists made a statement to tell what they had discovered. This statement is a principle of science.

Sometimes there may be an exception to the principle. In other words, the principle may not be true in a few cases. Rubber and water do not expand and contract as most materials do. If you stretch a rubber band with a small weight and then heat it gently, the rubber will contract. Then as it cools, it will expand again.

At certain temperatures, water also acts queerly. As water is cooled, it contracts until it reaches a temperature of about 39° F. Then if it is cooled still more, it expands until it freezes at 32° F. or a little below this temperature. (This unusual expansion of water as it is cooled below 39° F. is the reason why ice floats instead of sinking.) Below 32° F., the ice that is formed contracts and expands as most other solids do. Even though a science principle may not be true in all cases, there are not many exceptions. So it is usually safe to use the principle whenever we can to explain things that we see happening.

What material do the test tubes contain? Why do you think so?

SELF-TESTING EXERCISES

1 Complete each sentence below with the word that will make it a true statement.

a When a wire gets longer because it is heated, we say that it _____.

b When a wire gets shorter because it is cooled, we say that it _____.

c A statement that tells what usually happens under certain conditions is called a _____ of science.

d Most materials _____ when heated.

e Most materials _____ when cooled.

2 Let us suppose that you notice something that seems to be just opposite to some principle of science. What may be the explanation?

3 Why would it be poor thinking to state a new science principle after doing only one experiment or a few experiments?

WHAT OBSERVATIONS CAN BE EXPLAINED BY THE PRINCIPLE OF EXPANSION AND CONTRACTION? You have just learned one science principle. *Most materials expand when heated and contract when cooled.* When you have learned a principle of science, you will find that it can be used to explain a great many happenings. To see how useful a science principle is, think about some everyday observations that can be explained by the principle of expansion and contraction.

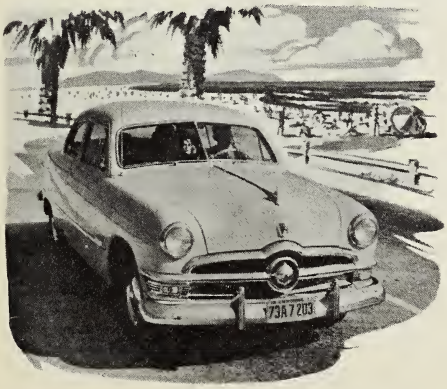
Now you can explain why you are able to separate two glasses. Cold water makes the inside glass contract, while hot water makes

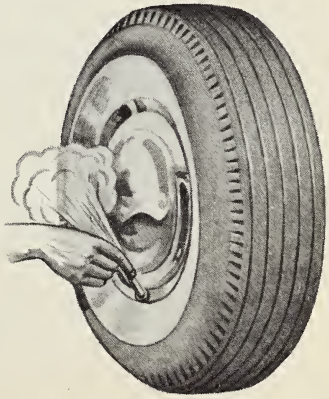
the outside glass expand. Heating also makes the water in a kettle expand until it overflows. And heating makes the metal in a jar cap expand. The metal expands more than the glass. This makes it possible to get the cap off.

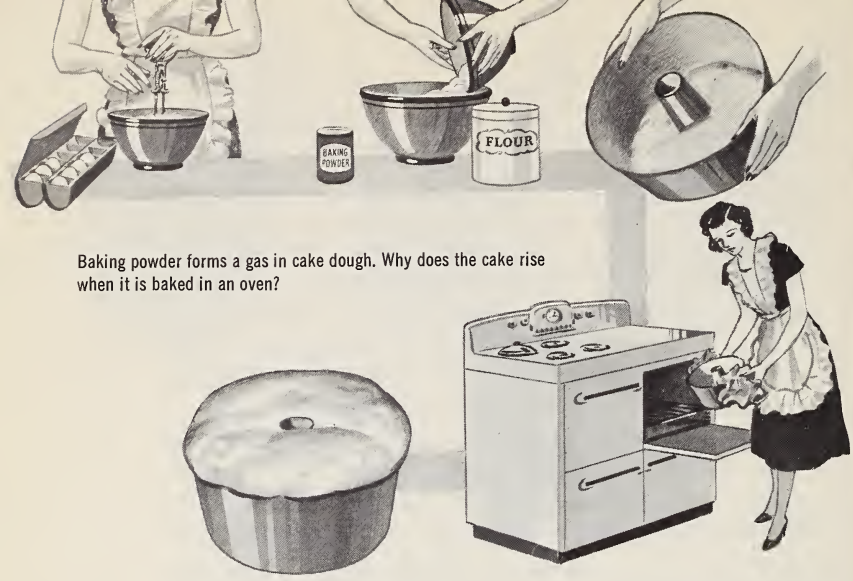
You have often used a thermometer to tell you how hot or cold it is. The mercury or colored alcohol rises, and you know that the air is getting warmer. Or the liquid falls, and you know that it is getting colder. Of course, what happens is that the liquid in the bulb expands when heated and is forced upward in the tube. When the air gets colder, the liquid in the bulb becomes cooler and contracts. Then the liquid in the tube falls.

Here is another everyday happening that you can explain when you know how heating affects liquids. To keep an automobile engine from becoming overheated, the radiator should be nearly full of water. Usually the water is cold when you pour it in. If you fill the radiator and then drive the car until the water gets very hot, you will find that water is running out of the radiator. Perhaps you have noticed the directions on a can of antifreeze solution used in automobile radiators. The directions say, "Do *not* fill the radiator entirely full of water. If you do, some of the antifreeze solution will be lost as you drive." You can now see the reason for these directions.

In hot weather, people often let some air out of their tires. Why?







Baking powder forms a gas in cake dough. Why does the cake rise when it is baked in an oven?

Now think about a question that one boy asked his science teacher. The question was this: Why is one end of a railroad bridge set on rollers? At first you might not believe that this question could be answered by using the principle. You have not studied anything about bridges, but you have found out what heating and cooling do to solids. If you stop and think a moment, you will see that the principle answers this question.

In most parts of our country, there are great changes in temperature during the year. The change in temperature from the hottest day in summer to the coldest day in winter may be as much as 100° F. In a steel bridge 1000 feet long, this change of 100° F. will make a difference of about 7 inches in the length of the bridge. You can understand why one end must be free to move, why it must be set on rollers. Some method must be used to allow room for the expansion and contraction of the steel. Otherwise the steel would bend or break.

If you help your mother wash the dishes, you know that you should never pour very hot water on thick drinking glasses or other thick glass dishes. If you do, the glass will often crack. You can explain what happens by using the principle you have just

learned. The hot water makes the glass expand. If the glass is very thick, it will not get heated all the way through at once. The outside of the glass will become heated before the inside. So the outside of the glass will expand faster than the inside. Something has to give way, and so the glass cracks. If you want to wash thick glass in hot water, the temperature must be raised gradually either by adding the hot water very slowly or by heating the water slowly on a stove.

As you see, a science principle can be used to explain many things that happen every day. To understand a principle, you must practice using it to explain the things going on around you.

SELF-TESTING EXERCISES

1 Why is a principle of science a useful thing to know?
2 How does the principle of expansion and contraction explain how a thermometer works?
3 Why is one end of a long steel bridge sometimes set on rollers?

One summer day, these tracks were bent nearly 5 inches out of line. How do you think this happened?

When telephone men string new wires, they must find out the temperature for that day before they tighten the wires. Why?

PROBLEMS TO SOLVE

1 Why do water pipes sometimes burst when the water in them freezes?

2 When fruit is canned, the glass jar is usually filled to the top with very hot fruit and syrup. But when the jar is examined later on, it is not full. Explain.

3 A man who lived in a part of our country where the nights are cold and the days very hot filled the tank of his car with gasoline at night and let the car stand outdoors all the next day. What do you think happened? Explain.

4 If a fountain pen is filled with ink and carried on a very hot day, it will sometimes leak. Explain.

5 A football is pumped up in a warm room and is then used outdoors where the temperature is about freezing. Will it become harder or softer when it is taken outdoors? Explain.

6 Milk contains a large amount of water. How can you explain what has happened to the milk in the bottle shown on page 104?

7 A bottle with only a little milk in it was taken from a very cold refrigerator and set on a kitchen table. Soon there was a fizzing sound, and bubbles began to come out around the paper cap of the bottle. Explain why this happened.

8 Explain how you might make a thermometer, using air instead of mercury. (Refer to Experiment 3, page 108.)

9 Some science classes do an experiment with a metal ring and ball. When the ball is cold, it will pass through the ring. When the ball is heated, it will not pass through the ring. Why not? How could you pass the hot ball through the ring?

Rivet before forming the head

Rivet after forming the head

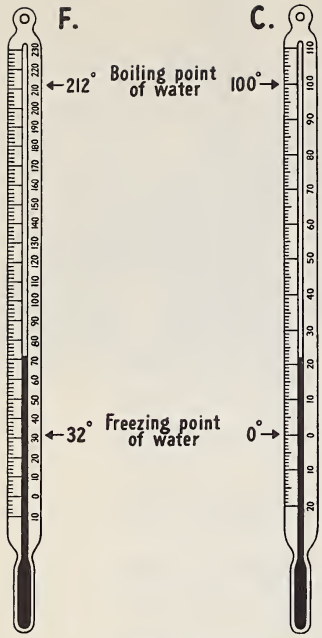
10 The steel beams in skyscrapers and bridges are often held together with rivets. The rivets are put in and hammered down while hot. They hold the beams more tightly together than rivets that are put in cold. Explain why.

11 Why do thin drinking glasses not break so easily as thick ones when placed in very hot water?

12 In Unit 3 you used a theory to explain some observations. In this unit you used a principle of science. What differences can you see between a principle and a theory?

13 In the problems above, you have seen that many things are explained by the principle you have learned. Try to find some other everyday happening that can be explained by this principle. Write it up as a problem like the ones above and see whether your classmates can explain it. Perhaps you can think of several such problems.

How can you explain why the pavement of this busy highway suddenly buckled?



Here are two kinds of thermometers. The Fahrenheit thermometer is the one that we ordinarily use. Scientists usually use the Centigrade thermometer in their work. The abbreviation for Fahrenheit is F. The abbreviation for Centigrade is C.

The freezing point of water is the temperature at which water freezes, or changes from a liquid to a solid. This same temperature is the melting point of ice. In other words, water melts and freezes at the same temperature. The boiling point of water is the temperature at which water boils.

What is the freezing point of water on each thermometer? What is the boiling point of water? How many degrees between the freezing point and the boiling point on each thermometer? Why must we say which thermometer scale is used when we mention a temperature?

2 What changes of state are caused by heating materials?

How are solids changed to liquids? You know that solids, liquids, and gases are the three states of matter. You know also that each state of matter has certain characteristics of its own. Now you are going to find out how materials change from one state to another.

If a cake of ice, or water in the solid state, is brought into a warm room, the ice melts. In other words, it changes to a liquid. Water can exist as ice only when it is at or below freezing temperature. If the air is warmer than this, some of the heat from the air goes into the ice. Then the ice melts. You can see this happen if you put some ice in a glass of water. The water will get much colder, and the ice will melt. The heat from the water melts the ice.

Many other solids are changed to liquids when they are heated enough. You do not see these solids in a liquid state very often

Melting points of some common materials

Material	Degrees Fahrenheit	Degrees Centigrade	Material	Degrees Fahrenheit	Degrees Centigrade
Alcohol, ethyl	−202*	−130*	Salt, common	1481	801
Mercury	− 38	− 39	Silver	1761	961
Carbon tetrachloride	− 9	− 23	Gold	1945	1063
Wood's metal†	158	70	Copper	1981	1083
Moth balls (naphthalene)	176	80	Iron	2795	1535
Tin	450	232	Quartz (sand)	2912-3092	1600-1700
Lead	621	327	Platinum	3224	1774
Aluminum	1220	660	Tungsten††	6098	3370

* A minus sign (−) before a temperature reading means below zero.

† A mixture of tin, lead, and other metals.

†† Tungsten has the highest melting point of all metals. It is used to make the wires that get white-hot inside electric-light bulbs. Tungsten is also called wolfram.

because they are seldom heated enough to make them melt. If you look at the table on this page, you will find the melting points of some common materials. This table tells you just how hot these materials must get before they change from solids to liquids. It also tells you how cold these materials must be to freeze, because the melting point and the freezing point are the same. If you would like to melt one of these materials, do Experiment 4.

Experiment 4 How does lead melt?

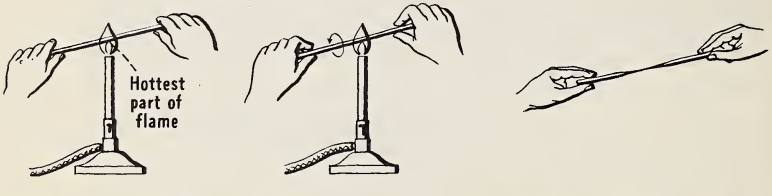
What you need: Pieces of lead; metal ladle (or tin can with stiff wire handle); pot holder; matches; gas burner (or other source of high temperature); wooden sticks; tin can.

What you do: Put the pieces of lead into the ladle. Heat them over a blue gas flame. Watch the lead while it is melting. Does a piece of lead seem to change quickly from solid to liquid? Or does it seem to get soft and waxy and then liquid?

Use a wooden stick to scrape the dull lead oxide from the melted lead. What does the melted lead look like? Notice how easily it flows. Pour the melted lead into a tin can to cool. When the lead is cool, look at it again. How does the lead look now?

We cannot include some common materials in the table, because they do not have a definite temperature at which they melt or freeze. Butter is hard when it is cold. As it is warmed, it becomes softer and softer. Finally, it changes to a liquid if the temperature is high enough. Sealing wax and glass are two other materials that change gradually from a solid to a liquid. Glass is easily shaped because it becomes softer and softer as it is heated. It does not change suddenly from a solid to a liquid. Glass is usually heated until it is red-hot. Then it can be easily shaped by blowing air into it, by pressing it, or by bending it. If you have never heated glass so that it can be bent or shaped, you can do so when you do Experiment 5.

Experiment 5 How does glass act when it is heated?



What you need: Pieces of glass tubing at least 6 inches long; matches; gas burner (or other source of high temperature); heavy tweezers (or small pliers).

What you do: Hold one end of a piece of glass tubing in the hottest part of a gas flame until it is red-hot. Does the tubing change shape? Touch the soft glass with the end of a piece of cold glass or with tweezers. What happens?

Heat the middle of a piece of glass tubing until it is soft. Notice how easily it bends. When the tubing is very soft, pull on both ends but do not pull the glass thread in two. Is the glass thread hollow or solid? Does it bend easily?

Heat the end of a piece of glass tubing until the hole is closed. Then before the glass cools, blow into the end you are holding in your hand. You should be able to blow a small bubble or bulb on the closed end of the tubing.

When heating glass tubing to bend, pull, or blow it, keep turning the tube in your fingers. Do not try to shape the glass in the flame. Heat the glass and then take it out of the flame for shaping. To bend glass, make the bend slowly.

Melted steel is poured into molds when it comes from the furnace. As the steel cools, it hardens into these huge blocks that can be stored until the steel is needed.

In thousands of factories and mills throughout the world, heat is used to change solids to liquids. Copper, iron, lead, aluminum, and other solid materials are melted and poured into molds to make parts for roller skates, bicycles, automobiles, trains, airplanes, cooking utensils, furnaces, tools, and many other things that we use. Glass, rubber, and other plastics are heated and shaped while they are still soft. From what you have just read, you can easily understand why scientists and engineers have spent many years trying to find out what heat does to materials.

To work with certain materials, people learned that they had to have very high temperatures. Until these materials were very hot, they could not be easily shaped. The highest temperature we can get from the sun is only about 135° F. An open fire of wood, coal, or charcoal gives a temperature of about 750° F. Such temperatures are not high enough to melt iron and some other metals. Much higher temperatures are needed, and people found out how to get them. In the huge furnaces used to melt iron and make steel, the temperatures are over 3000° F.

SELF-TESTING EXERCISES

1 Complete each sentence below with the word or words that will make it a true statement.
   a The melting point of a material is the same as its_____point.
   b When a solid is heated to its melting point, it changes to a_____.
2 Why do we seldom see iron and copper in the liquid state?
3 Why do scientists and engineers want to know what heat does to materials?
4 Which of the following materials have definite melting points? Butter, sealing wax, copper, lead, glass, aluminum, mercury, ice. (Refer to the table on page 117.)

HOW ARE MATERIALS CHANGED TO GASES? A few hours after a rain, puddles of water on streets and sidewalks disappear. Wet clothes hung out on the line soon dry. Water left in an open pan finally disappears. You see these things so often that you pay little attention to them. Do you know what actually happens to the water? It might soak into the ground or drip from the wet clothes. Some of it does. But you know that water cannot soak through a metal or glass pan. We say that the water "dries up." And we know that the water has changed to a gas and mixed with the air.

Scientists have a word to describe the changing of a liquid to a gas. The word is evaporation. We say that a material evaporates, or *vaporizes,* when it changes to a gas, or vapor. You can discover an important principle of evaporation by doing Experiment 6.

Experiment 6 Which evaporates faster, hot water or cold water?

1 How can you do an experiment to find out whether water evaporates faster when it is hot or when it is cold? What do you need for the experiment?
2 Try your experiment. What happens? What does this show?
3 What seems to be one good way to make water evaporate faster?

Experiment 6 shows one way to increase the speed with which water evaporates. Of course you are more familiar with water than with any other liquid. But other liquids also evaporate. To find out whether all liquids evaporate at the same rate, do Experiment 7.

Experiment 7 Do all liquids evaporate at the same rate?

1 Suppose that you have these liquids: water, oil, gasoline, alcohol, ether, and carbon tetrachloride. How can you do an experiment to find out whether they all evaporate at the same rate? What conditions must be the same for all the liquids? Why?

2 BEFORE DOING THE EXPERIMENT, BE SURE THAT THE ROOM IS WELL VENTILATED AND THAT THERE ARE NO OPEN FLAMES OR DEVICES THAT MIGHT CAUSE SPARKS. The vapors from gasoline, alcohol, and ether may explode when mixed with the right amount of air.

3 Now do the experiment. What happens?

4 How does this answer the question of the experiment?

Each liquid has its own rate of evaporation. Gasoline, alcohol, and ether evaporate quite rapidly. Other liquids, such as oils and mercury, evaporate very slowly. In fact, they seem not to evaporate at all. Yet scientists find that they do evaporate even when cold.

Another interesting fact about evaporation is that some solids evaporate without melting. Probably you think that ice must melt and change to liquid water before it can evaporate. Of course that is what usually happens. But if you watch the icicles on the north side of a house in winter, you will discover a strange thing. During very cold weather, the icicles become shorter and shorter even though the temperature of the air is below the melting point of ice. They become shorter because the ice evaporates! Many women know that laundry will freeze dry if they hang it out on a very cold day. The water in the clothing first freezes and then evaporates. Moth balls in a box of clothing get much smaller or disappear completely, because they change directly from a solid to a gas, or vapor.

When shallow pools of sea water evaporated, huge sheets of salt were left. In what kind of climate do you think salt can be obtained easily and cheaply in this way? Why?

Now you have learned these principles of science about evaporation: (1) Liquids change to gases, or evaporate, at all temperatures. (2) Heating increases the speed of evaporation. (3) Different liquids evaporate at different rates. (4) Some solids evaporate without melting.

You can use the principles of evaporation to explain many changes that take place in the world around you. Perhaps you have noticed that the grass is covered with dew in the early morning on a summer day. Shortly after the sun rises, the dew disappears. What has become of it? You can answer this question by remembering what you have learned about evaporation. Because it is cool in the early morning, evaporation takes place very slowly. But when the sun comes up, the grass and dew are warmed. So the speed of evaporation is increased. The dew changes to water vapor and soon disappears into the air.

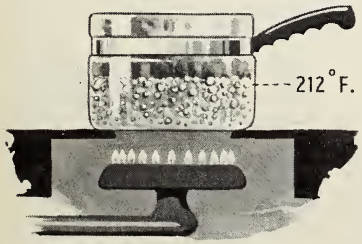
In removing stains from clothing, you have probably used carbon tetrachloride or some other cleaning fluid. You may remember that the spot wet with the cleaning fluid dried almost immediately —much more quickly than a spot of water dries. What you have learned tells you that you used a liquid that evaporates very quickly.

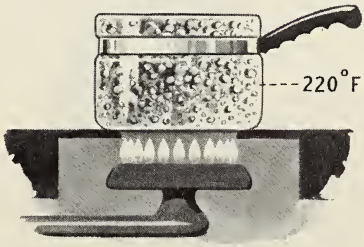
If water or any other liquid is heated hot enough, it will boil. When a liquid boils, it is so hot that some of the liquid changes to a gas and forms bubbles inside the liquid. These bubbles rise to the surface and the gas inside them mixes with the air. The hot gas that is formed from water when it boils is called steam. In a container that is open to the air, a liquid cannot be heated any hotter than its boiling point. If a hotter fire is made under boiling water, it merely boils faster and changes to steam more rapidly. Its temperature stays at 212° F., or 100° C. This temperature is the boiling point of water.

In the table on page 124, you can find the boiling points of some common liquids. Notice the boiling points of water, alcohol, and ethylene glycol (eth'i lēn glī'kōl). Either alcohol or ethylene glycol may be mixed with water in automobile radiators in winter to keep the water from freezing.

SELF-TESTING EXERCISES

1 Complete each sentence below with the word or words that will make it a true statement.
   a In evaporation, a liquid changes to a _____.
   b Liquids can evaporate at _____ temperatures.
   c The speed of evaporation can be increased by _____ a liquid.
   d Some solids evaporate without _____.
2 Why does dew disappear after sunrise?
3 Name some solids that can evaporate without melting.
4 Look at the pictures below. What does the picture on the left show? Does the other picture show correctly what happens when you turn the burner up?





Boiling points of some common liquids

Liquid	Degrees Fahrenheit	Degrees Centigrade	Liquid	Degrees Fahrenheit	Degrees Centigrade
Ether	94	35	Turpentine	318	159
Carbon tetrachloride	171	77	Ethylene glycol	388	198
Alcohol, ethyl	173	78	Glycerine	556	291
Water	212	100	Mercury	674	357

PROBLEMS TO SOLVE

1 **a** Why do you think alcohol gradually disappears from an automobile radiator?

b Why do you think some people prefer ethylene glycol even though it costs much more than alcohol?

2 Why must a person add more water to the radiator of an automobile if he is taking a long trip at a high speed than if he is taking a short trip at a low speed?

3 Popcorn kernels contain a great deal of water. When they are heated, they pop. What do you think causes the popping?

4 If you are boiling potatoes, how should the gas be regulated so as to cook the potatoes in the shortest time with the least fuel? Explain.

5 Suppose that butter had a definite melting point just as ice has. How would this affect our ways of using butter?

6 Glycerine is sometimes put in bread to keep it moist and fresh. Can you find in the table on this page a reason why bread with glycerine stays more moist than bread with water as its only liquid?

Which do you think is a better time to water the garden? Why?

Which is the correct way to take care of each of these things? Explain your answer.

7 Sometimes in the early morning there is a fog. A fog is made of many tiny drops of water floating in the air. Soon after the sun comes out, the fog slowly disappears. Explain why this happens.

8 Tell how each of these facts can be explained by what you have learned about evaporation.

a The spout of a maple-syrup pitcher usually has solid pieces of maple sugar on it.

b The air around a lake has more water vapor in it than the air in a desert.

c Fudge becomes very hard if left on a plate exposed to air.

d After damp clothes have been ironed a minute or two with a hot iron, the clothes become dry.

e Clothes dry more quickly in the sun than in the shade.

9 Thermometers used outdoors are often filled with colored alcohol. Why can these thermometers not be used to test the temperature of candy while it is cooking? (See the table on page 124.)

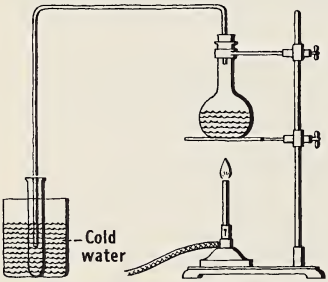
10 If a fire breaks out in the projection room of a motion-picture theater, the opening into the theater must close automatically. One way to do this is to have a sliding door hung on a chain. One link of the chain is made of Wood's metal or some similar mixture of metals. Refer to the table on page 117 and tell why you think such a door would close at once in case of fire.

11 A man bought some gum camphor (a solid) at a drug store. He left it on a shelf of the medicine cabinet tightly wrapped in paper. A few months later, he found the package still sealed but empty. How would you explain what happened to the camphor?

3 What changes of state are caused by cooling materials?

How are gases changed to liquids? You have already seen that you can change liquids to gases by heating them. What do you suppose will happen if you cool a gas? In other words, you might try to *predict* what happens to gases when they are cooled. Predict means tell what you think will happen before it happens. A scientist is always trying to predict what will happen. He observes something happen, and he notices carefully the conditions under which it happens. Then he uses what he has learned to predict what will happen in other situations like the one he has observed. After you have predicted what will happen to gases when they are cooled, do Experiment 8 to find out if your prediction is correct.

Experiment 8 What happens to steam when it is cooled?



1 What happens when the water in the flask is heated enough?

2 What is the beaker of cold water for?

3 What change takes place in the test tube?

Water is the liquid that you most often notice changing to a gas. It is also the gas you most often notice changing back to a liquid. You see water boil when it is heated to 212° F., or 100° C. As it boils, it turns into bubbles of steam that pass into the air. This steam is as invisible as the air itself. You could not see the steam in Experiment 8. Steam is water vapor that is at or above the boiling point of water. When steam is cooled below the boiling point, it changes back to liquid water again. We say that it condenses. The changing of a gas to a liquid is called condensation.

What is in the space between the teakettle and the white cloud? What is the white cloud? How is it formed?

Most people say that the white cloud above the spout of a kettle is steam. You know that it cannot be real steam because steam is water vapor, which is invisible. You should now be able to explain what the white cloud really is. As the invisible steam comes out of the spout, it mixes with the cooler air. The steam is cooled, and it condenses into many tiny drops of water that float in the air. The white cloud is made of these tiny drops of liquid water. You have often seen such clouds formed from condensing steam. Even the clouds in the sky are formed from water vapor that condensed into tiny drops of liquid water.

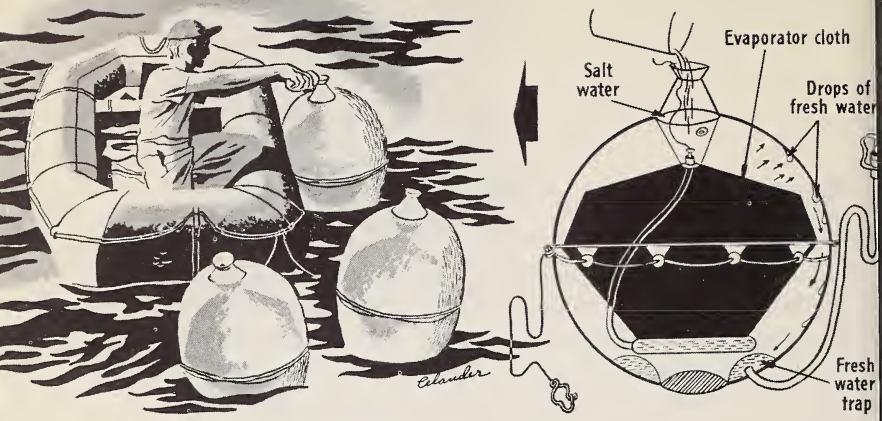
Water that has been changed into steam and then condensed in a clean tube or container is called *distilled* water. The process is called *distillation*. Other liquids besides water can be distilled. Distillation is very important in making gasoline, turpentine, and many other materials. You can distill some water in Experiment 9.

Experiment 9 How is salty water changed by distilling it?

1 How can you use the apparatus of Experiment 8 to find out whether salty water is changed by distilling it?

2 Distill some salty water. Has the salty water been changed by distilling it? How can you tell whether it has been changed?

Sometimes distillation is the best way to get good drinking water. Ocean water is so salty and bitter that it cannot be used for drinking. Ships usually carry enough fresh water for a voyage. But if they run out of fresh water, ocean water can be distilled. In most *stills,* water is changed to steam. The salt and other solid impurities in the water do not change to gases when the water



Life rafts for ships and airplanes often carry stills like the ones above. The salty water is poured into the opening and drips onto the black cloth, which is heated by the sun. The heat makes the water evaporate. When the water vapor hits the cooler sides of the still, it condenses and runs down into the trap. The salt remains on the black cloth.

boils. Instead, they stay in the container while the steam goes into another container, where it is condensed into pure water.

Have you ever noticed that drops of water sometimes collect on the inside of a windowpane? Sometimes these drops are very small and merely form a film over the glass. But you can tell that the film is water if you run your finger through it. If you have ever blown your breath on a cold windowpane, you have seen such a film collect on the glass. Where does this water come from?

You have already learned that water is always changing to a gas and mixing with the air. Air can hold only a certain amount of water vapor at a certain temperature. Hot air can hold a great deal of water vapor. Cold air can hold much less. Now suppose that water has been evaporating into the air and that the air has taken up all the water vapor it can hold. What do you think will happen if the air is cooled? Some of the water vapor will have to come out of the air. When it comes out of the air, it condenses into liquid water. Water on a windowpane is formed in this way. The air in the room contains water vapor. The windowpane is cold, and it cools the air next to it. Then some of the water vapor condenses on the glass. You can do Experiment 10 and cause some water vapor to condense.

Experiment **10** What causes water vapor in the air to condense?

What you need: Shiny metal cup (or can); cold water; crushed ice; salt; spoon.

What you do: Be sure that the outside of the cup is dry. Pour cold water into the cup until it is about half full. Be careful not to wet the outside of the cup. Why? Now watch to see what happens. Does a thin layer of moisture form on the outside?

If not, add some crushed ice to the water and stir the mixture. Keep on adding crushed ice until you see a layer of moisture. You may have to add some salt to make the ice melt faster. Where does the moisture on the outside of the cup come from? How do you know? What does this experiment show about the condensation of water vapor?

When air has a large amount of water vapor in it, it needs to be cooled only a few degrees to cause condensation to take place. If there is only a small amount of water vapor in the air, the air must be cooled many degrees before condensation takes place.

Scientists know that all gases can be condensed if they are cooled enough. Even air can be changed to a liquid that looks like water, but the boiling point of liquid air is lower than 300° below zero F. A glass of liquid air boils rapidly if it is set on a block of ice. The liquid air soon changes completely to ordinary air because the ice is more than 330° F. hotter than the liquid air. The boiling points of hydrogen and helium are both much lower than that of liquid air. Helium is the most difficult gas to condense. Scientists have found that helium must be cooled lower than 450° below zero F. to make it condense.

Under the right conditions, some vapors can change to solids without first becoming liquids. When this happens, the condensing vapors form crystals. When water vapor condenses at temperatures below freezing, it forms beautiful crystals of snow and frost. You can see them in the picture on this page.

The air on the mountain top is colder than the air in the valley. How does this explain why you can see snow and fruit trees in bloom at the same time?

SELF-TESTING EXERCISES

1 Complete each sentence below with the word or words that will make it a true statement.

a To change a gas to a liquid, the gas is _____.

b The white cloud around the spout of a teakettle of boiling water is made of _____.

c Purifying water by evaporating it and condensing the steam in a clean tube or container is called _____.

d Cold air can hold _____ water vapor than hot air.

e Water vapor will condense from air if the air is _____ enough.

f If air has a large amount of water vapor in it, it must be cooled _____ to cause condensation than if it contains only a small amount of water vapor.

2 How do scientists predict what will happen in certain situations?

3 How is salty water changed by distillation? Explain what happens.

HOW ARE LIQUIDS CHANGED TO SOLIDS? You have seen many examples of what happens to liquids when they are cooled. Liquid water changes to ice at 32° F., or 0° C. You may have

Sulphur is mined by first melting it underground with very hot water. Then the melted sulphur is pumped to the surface and put into large storage vats, where it hardens as it cools.

seen your mother cover glasses of jelly by pouring a layer of hot liquid paraffin over them. The liquid paraffin soon changes into solid paraffin and keeps the jelly from spoiling. The wax at the top of a candle melts while the candle burns. Soon after the candle is put out, the liquid wax becomes solid again. Lard or some other fat is melted to fry doughnuts and potatoes. After the pan cools, the melted fat changes into a solid again. Lead is melted and poured into molds of different shapes. When the lead cools, it hardens again in the shape of the mold.

Every liquid can be changed to a solid if it is cooled enough. Some liquids need to be cooled a great deal. Such a liquid as alcohol has to be cooled to over 200° below zero F. to freeze it. Mercury can be changed to a solid if it is cooled to about 38° below zero F. If some liquid air is poured on liquid mercury, the mercury will become hard enough to drive a nail. Liquid air has a temperature of more than 300° below zero F.

You already know that an antifreeze should have a high boiling point. But, of course, it is also important for an antifreeze to have a low freezing point. The radiator of an automobile is usually filled with water, which freezes at 32° F. The antifreeze is used to lower the freezing point and keep the water from freezing in cold weather. A mixture of antifreeze, such as alcohol and water, has a much lower freezing point than that of water alone.

Now recall what you have learned: (1) If any gas is cooled enough, it may condense. (2) Steam is changed to liquid water by cooling it. (3) In distillation, water or some other liquid is changed to a gas to separate it from its impurities. Then the gas is cooled to change it to a liquid again. (4) Water vapor in the air is condensed when the air is cooled enough. (5) Air can be made liquid by cooling it enough. (6) Under the right conditions, some gases condense into solid crystals without first becoming liquid. (7) If any liquid is cooled enough, it changes to a solid.

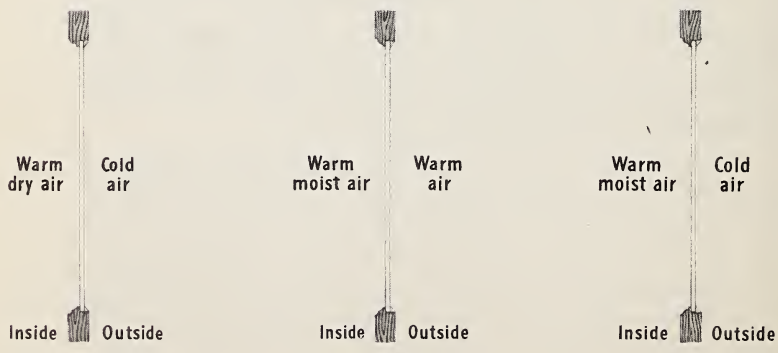
SELF-TESTING EXERCISES

1 To what temperature must water be cooled before it will change to a solid?
2 Why is mercury a liquid at ordinary temperatures?
3 Why is a mixture of water and alcohol used in the radiator of an automobile in cold weather?

PROBLEMS TO SOLVE

1 Most of our rain comes from water that was once in the salty ocean, but rain is not salty. Explain why there is no salt in rain water.
2 Look at the picture of the locomotive on page 104. How do you explain the white cloud that you see?

Below are three windows with different kinds of air inside and outside the windowpane. What is likely to happen on the inside of each window?



Explain what has happened in each of these pictures.

3 **a** On a very cold day, your breath usually forms a white cloud. What is this cloud?

b Why does your breath not form a cloud on a warm day?

c Will the cloud show more quickly when the air is moist or when it is dry? Why?

4 Look at the picture on page 104. How can you explain the spout of moisture the whale gives off when it comes to the surface to breathe?

5 What change in the air causes clouds to form?

6 In summer, the concrete walls in a basement sometimes "sweat." In other words, drops of water condense on them. How do you explain this?

7 Maple sugar is obtained by putting the sweet sap of maple trees in large kettles or tanks and boiling it. How does this help obtain the sugar?

8 If moth balls are kept in a closed glass jar, after a time you may find tiny crystals of moth-ball material on the inside of the jar. How could they get there?

9 How many things can you find in your home that were made by melting some material and then letting the liquid change back to a solid? Make a list of the things that you find.

4 How do heating and cooling change the action of molecules?

HOW DOES THE MOLECULAR THEORY EXPLAIN EXPANSION AND CONTRACTION? You have learned three ideas of the molecular theory: (1) All matter is made up of small particles called molecules. (2) There are spaces between molecules. (3) The molecules are always moving. If this theory is a good one, it ought to explain why materials expand and contract, why heating makes solids melt and liquids evaporate, and why cooling makes gases condense and liquids freeze. To explain why materials expand and contract, you will have to learn another idea of the molecular theory: (4) The molecules of a material move faster when a material is heated and more slowly when a material is cooled. Scientists have very good reasons for believing that this is true.

Now let us see what happens in a solid, such as iron wire, when it is heated and cooled. Heating an iron wire makes the molecules in the wire move faster. When they move faster, they bump into each other harder. As the iron wire gets hotter, its molecules knock each other farther apart. This makes the wire longer and thicker, and so it expands. When the iron wire cools, the molecules move more slowly. They do not knock each other so far apart. They get closer together, and so the wire contracts.

Perhaps this will be clearer to you if you imagine a swarm of bees bunched together on a limb. They crawl slowly over each other in an almost solid mass. You come up and make them angry. They begin to fly around much faster. To do this, they need more room. So the swarm spreads out until it is many feet across.

Like solids, liquids and gases also expand when heated and contract when cooled. Heating makes the molecules of a material speed up and go farther apart. Then there is more space between the molecules, and the material expands. Cooling has just the opposite effect. It makes the molecules slow down and come closer together. Then there is less space between the molecules, and the material contracts. So the molecular theory explains how materials expand when heated and contract when cooled.

SELF-TESTING EXERCISES

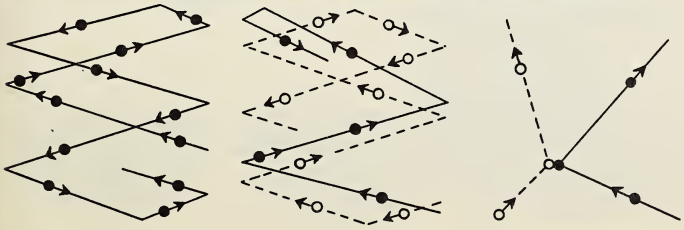
1 What happens to the molecules of a material when it is heated and when it is cooled?

2 How are the expansion and contraction of materials like the actions of a swarm of bees?

HOW DOES THE MOLECULAR THEORY EXPLAIN MELTING AND FREEZING? To explain melting and freezing with the molecular theory, you must imagine how the molecules in a solid, such as ice, are arranged differently from those in a liquid, such as water. Scientists believe that the molecules in a solid are held together so that they cannot slip past one another. Each molecule is moving back and forth near one spot because it cannot get loose from the pull of its neighbors. In a liquid, the pull of each molecule on its neighbors is weaker, so that the molecules slide around very easily.

Now what would weaken the pull of the molecules of ice on one another? When you are tightly held by several of your friends, how can you get loose? You can do it by becoming very active and jumping around until you break loose. Scientists think that this is just what the molecules do, even though they do not hold together with hands. Heating a piece of ice makes the molecules move so vigorously that they jerk loose from one another and begin to slide around freely. When this happens, the ice becomes liquid water. It has melted, and it no longer holds its shape. Cooling some water makes the molecules move around more slowly. When the temperature goes below the freezing point, the molecules are held together. When this happens, the liquid water has become ice. It has frozen, and it holds its shape.

The solid line in the first diagram shows the path of one molecule. The second diagram shows the paths of two molecules. What happens when two molecules collide, as in the third diagram?



SELF-TESTING EXERCISES

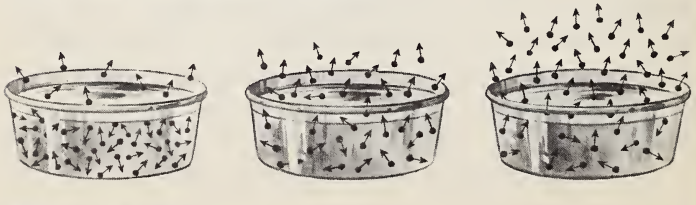
1 How do the molecules in ice act differently from those in water?
2 When a piece of ice is heated, what happens to the molecules?
3 What happens to the molecules when water freezes?

HOW DOES THE MOLECULAR THEORY EXPLAIN EVAPORATION AND CONDENSATION? You can explain how the evaporation of liquids takes place by using the molecular theory. The molecules of a liquid are moving about in all directions. In a gas, such as air or water vapor, the molecules are moving about in much the same way. But they are hundreds of times farther apart. In both liquids and gases, there are so many molecules that they are constantly bumping into one another.

In spite of their speed, the molecules of a liquid pull on one another and stay fairly close together. But sometimes a molecule that is moving up toward the surface misses all of its neighbors and shoots right out into the air. And some of the molecules on the surface get hit very hard by molecules underneath them. Such a jolt knocks them entirely loose, and they go flying out into the air. The molecules that are loose from one another and very far apart are now a gas instead of a liquid. If the liquid is water, the free molecules are now water vapor.

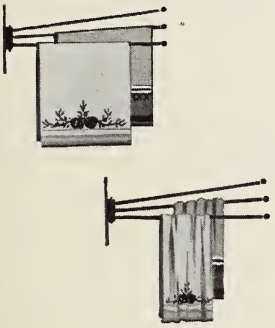
During evaporation, the molecules of a material simply escape from the liquid and go out into the air. They are very far apart and free from one another. So they form a gas instead of a liquid. When the liquid is heated, the molecules move faster. So more molecules fly out into the air. Of course this means that water evaporates more rapidly when it is heated, and that is exactly what you found in Experiment 6.

Which pan has the hottest water? How do you know?



The molecules of a liquid knock each other farther apart when the liquid is heated. The hotter the liquid gets, the harder the molecules hit each other and the farther they knock each other apart. When the temperature reaches the boiling point, some of the molecules knock one another so far apart that a bubble of gas is formed under the surface of the liquid. If the liquid is water, the bubble contains steam. This bubble rises to the top of the water, and the steam mixes with the air. If you keep on heating the water after it begins to boil, bubbles of steam form more rapidly. You know that in an open container a liquid cannot be heated higher than its boiling point. The extra heat simply makes more molecules fly apart and form bubbles of gas. The liquid boils faster, but it does not get any hotter.

You can also explain what happens when a gas condenses. The molecules in a gas, such as water vapor, are moving rapidly and very far apart. As long as the air is warm enough, the molecules form a gas. But if the air becomes cooler, the molecules of water vapor slow down and come close enough together to form tiny drops of water.



Which will dry faster? Use the molecular theory to explain your answers.

What changes of state are shown in each of these pictures? Explain why they took place.

SELF-TESTING EXERCISES

1 In your own words, tell what the molecules do when a liquid evaporates.
2 How does the molecular theory explain why a liquid cannot be heated hotter than its boiling point in an open container?
3 Why does water evaporate more rapidly when it is heated?
4 How does the molecular theory explain condensation?

PROBLEMS TO SOLVE

1 Make a drawing of a bottle of air. Use dots for the molecules. Now draw another bottle and show the molecules after the bottle has been heated.
2 Are there as many molecules of water in a quart of water at a temperature of 80° F. as in a quart of water at 60° F.? Explain.
3 Make a drawing of an iron wire showing its molecules. Now make another drawing that shows what happens when the wire is heated.
4 **a** Two pans of water are as nearly alike as possible. One is in dry air, and the other is in moist air. In which kind of air will the water evaporate more rapidly?

b How do you think the water molecules in the air act to make this difference in the speed of evaporation?
5 Solids usually dissolve faster in hot water than in cold water. Why?

How do you think the white lines in the street became wavy? On a winter day, what happens to the steam and hot water from a geyser? Why?

SUMMARY EXERCISES

1 Write down the big ideas of science you learned in this unit. Make them complete sentences.

2 Show that you know what the following words mean: expand, contract, Centigrade, Fahrenheit, freezing point, boiling point, melting point, evaporation, vaporize, predict, condense, distillation.

ADDITIONAL ACTIVITIES

1 Find out from the operator of a filling station whether his pump allows for expansion of gasoline in hot weather.

2 If you have a medical thermometer at home, examine it and see how it differs from outdoor thermometers in the way it is made and in the way it works.

3 Many stoves are equipped with metal thermometers or thermostats. Find out how they work. What principle of science explains how they work?

4 You can make the most important part of a metal thermometer or thermostat. Get a thin strip of brass about ½ inch wide and 8 inches long. Also get a similar strip of iron or steel. Drill or punch several holes through both strips and fasten them together with rivets or bolts. Heat them in the flame of a gas burner. What happens? How can you explain it?

5 The temperature of your schoolroom is probably regulated by a thermostat. Find out how the thermostat works.

6 Invent some way to make small amounts of expansion and contraction move a pointer. Use your method to show your class the expansion and contraction of a stretched rubber band when heated and cooled. (Do not apply a flame to the rubber. It will burn.)

7 If you have a balance or a pair of scales, show the difference in weight between hot and cold water. Fill a large bottle with cold water, and put a piece of glass across the top to make it just level full. Dry the outside with a cloth. Adjust the balance until it is just level. Then empty out the cold water, put hot water in its place, and see whether there is very much difference.

8 On a rainy day and on a dry day, make water condense on a cup, using the method of Experiment 10, page 129. To make your results more accurate, take the temperature of the water when the moisture appears. On which day does the moisture form at a higher temperature? Why?

9 **a** See how rapidly or slowly solids evaporate. Weigh a moth ball or a piece of gum camphor. Set it on a shelf for a few weeks and then weigh it again.

b Put a large crystal of iodine in an open dish. Look at it each day to see if it changes in size.

10 Get a Fahrenheit thermometer and a Centigrade thermometer. Study them and then answer these questions:

a We keep our homes at about 70° F. in winter. What would the reading be on a Centigrade thermometer?

b The temperature of the human body is 98.6° F. What is this temperature in degrees Centigrade?

c A candle melts at 127° F. At what temperature Centigrade does it melt?

d What temperature on a Centigrade thermometer corresponds to 0° F?

11 **a** Make two large wet spots with a damp sponge on the blackboard. Fan one spot. Which spot evaporates more quickly?

b What conclusion can you draw from this experiment?

c How could you use what you learned to make something evaporate more quickly?

12 In Experiment 9, page 127, water was changed into steam. Then the steam was changed back into water. Repeat this experiment, using muddy water in the flask. Is the water that condenses in the test tube also muddy? What use could you make of this experiment?

13 Find out which freezes first, ocean water or fresh water.

14 Make a wall chart of temperatures. Get a piece of wrapping paper 11 feet long. Make a bar on it 10 feet 8 inches long. Start the lower end of the scale at $-273°$ C. Make a mark every $10°$ (one inch apart) up to $1000°$ C. Place the Centigrade reading above the bar and the Fahrenheit reading below the bar. Put interesting temperatures at the proper points along the scale. Include the boiling point of water, freezing point of water, melting points of iron and gold, temperature of the oxyhydrogen blowpipe, and temperature of the human body.

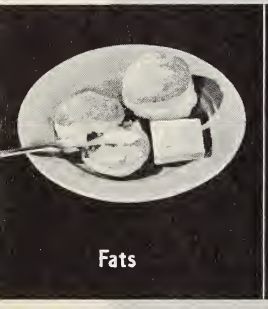
15 In reference books, read about the following topics: different kinds of thermometers; glass blowing; Pyrex glass; gases such as hydrogen, helium, argon, neon, ammonia, carbon dioxide, carbon monoxide, and others.

Growing and cultivating soybeans

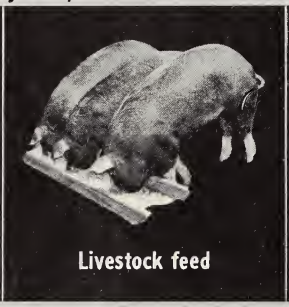
Harvesting soybeans

Mature soybean plant

Soybean pods

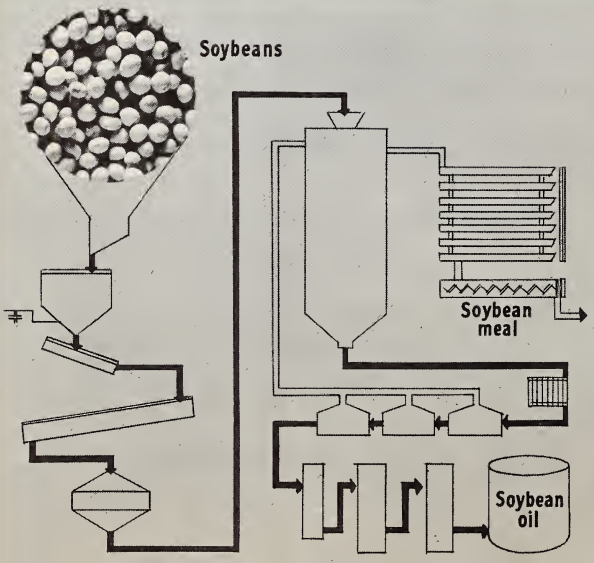


Fats



Livestock feed

Flours and other foods



UNIT 5

How can one material be changed into another?

When farmers plant soybean seeds, they harvest beans and other things as well. Of course, steering wheels, furniture, glue, cloth, and paints do not grow on plants. But scientists have learned how to use the materials in soybeans to make these and many other things. What do you think scientists must know in order to change one material into another? How have they found out some of these things?

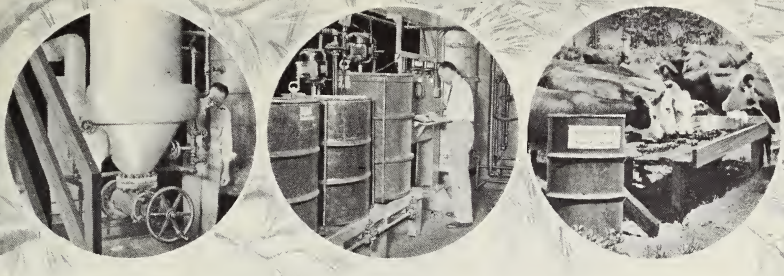
Sawdust can be made into boards. A kind of glue is mixed with the sawdust. Then the mixture is formed into boards under heat and great pressure. What kind of change is this?

LOOKING AHEAD TO UNIT 5

In Unit 1 you learned that a chemist studies materials. He learns what materials are made of and how he can make new materials out of the materials he already knows. He also learns how to change one material into another. He can mix two colorless liquids together and get a yellow solid. He can change liquid water into two invisible gases. A chemist can change coal or soybeans into hundreds of useful materials. You can also change one material into another material, and you have probably done it many times. Every time you burn a piece of wood, you change the wood into other materials. But so far in this book, you have not studied this kind of change.

When liquid water freezes, the water changes from a liquid to a solid. The state of the material changes, but it is still the same material. When liquid water turns into steam, only the form of the water changes. Steam is a form, or state, of water. When you dissolve sugar in water, you do not change the sugar into a different material. It is still sugar, and it still tastes like sugar. You can change the shape of a piece of rubber by stretching it, but it is still rubber. All these changes are examples of physical change. The material changes its form or shape, but it does not change into a different material.

The changes you will study in this unit are of a different kind. You have seen some of these changes many times. But some of them you have probably never noticed, because they take place so slowly. Others are made very quickly. When you hold a piece of



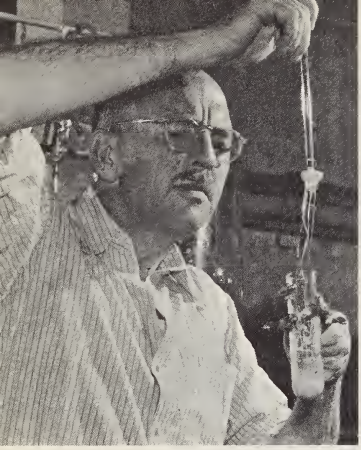
The cattle are feeding on molasses made from wood. This food material is made by cooking chips of wood with acid and other chemicals. What kind of change is this?

paper in the flame of a match, the paper catches fire and burns. You see a flame, some smoke, and then nothing but ashes. The paper has disappeared. It has changed into other materials with different characteristics. This change is very different from the change that happens when water freezes. The change that takes place when paper is burned is called a chemical change. In a chemical change, a material changes into another material with different characteristics.

Chemical changes are going on around you and even in your body all the time. The wood of a fallen tree in the forest slowly rots and falls apart. The food that you eat is changed into muscle, bone, and fat. Iron rusts, milk sours, and cloth fades. All of these changes in materials are chemical changes.

Scientists are interested in making some chemical changes take place, but they also want to prevent some changes. Burning is a chemical change. It gives us heat, but it may also destroy our homes. We do not like to have iron rust or cloth fade. But we want the chemical change that takes place when soft concrete changes to hard artificial stone. And we could not live without the changes that make plants and animals grow.

To change materials into other materials and to prevent some chemical changes, scientists had to discover what goes on during a chemical change. As you study this unit, you will find answers to such questions as: What are materials made of? How can we recognize a chemical change? How can we control chemical changes? How can we explain chemical changes?

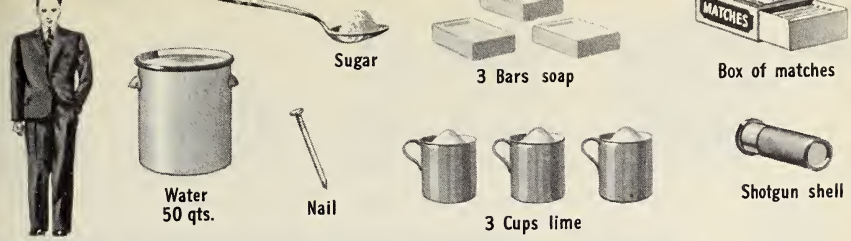


The scientist is showing how the first synthetic fiber was made. He is pulling a sample of the melted material from a test tube. Asbestos fibers are natural fibers.

1 What are materials made of?

WHAT ARE ELEMENTS AND COMPOUNDS? Before you can learn how to change one material into another, you must know what materials are made of. You know that there are many different kinds of materials. Some materials we use just as we find them on the earth. We call these natural materials or raw materials. Coal, iron ore, wood, oil, cotton, wool, salt, and water are some of the natural materials. Besides the natural materials that we use, scientists have discovered many new materials. We call these artificial materials or synthetic materials. They are made by putting natural materials together or by taking them apart. Celluloid, cellophane, bakelite, lucite, rayon, and nylon are only a few of these synthetic materials.

Some materials are elements, and some are compounds. An element is made of only one kind of material. Iron, gold, silver, mercury, and sulphur are examples of elements. Because an element is made only of itself, elements are the building blocks of our materials. All of the 500,000 different materials in the world are made from less than 100 elements. If you could take apart everything from roller skates and candy to elephants and trees and put the different elements in separate piles, you would have less than 100 different piles.



We can make things from elements alone, or we can put elements together to make compounds. A compound is a material that is made of two or more elements. Water, carbon dioxide, and salt are compounds that are made of two elements. Sugar is a compound made of three elements. Even our bodies are made of elements and compounds. The body of a man weighing 160 pounds contains about fifty quarts of water (a compound of the elements hydrogen and oxygen), enough of the element iron to make a large nail, a teaspoonful of sugar (a compound of the elements carbon, hydrogen, and oxygen), enough fat (a compound of carbon, hydrogen, and oxygen) to make several bars of soap, several cups of the element calcium, enough of the elements sulphur and phosphorus to make a large box of matches, and enough of the element potassium to make the powder for a small shotgun shell. Experiment 1 will help you understand the relation between an element and a compound.

Experiment 1 What happens when mercuric oxide is heated?

What you need: Teaspoon; mercuric-oxide powder; Pyrex or hard-glass test tube; paper plug for test tube; ringstand and clamp (or other support for test tube); matches; gas burner (or other source of high temperature); wood splinters; small porcelain or glass dish.

What you do: Pour not more than one eighth of a teaspoon of mercuric-oxide powder into the test tube. Put the paper plug in the mouth of the tube. Then support the test tube just over the hottest part of the burner flame. After a minute or two, look at the side of the tube about halfway up. What do you see?

Now light a wood splinter and let it burn a little. Then blow out the flame. Quickly remove the paper plug and plunge the glowing splinter into the test tube. What happens?

Put the paper plug back in and heat the test tube until all of the mercuric-oxide powder is gone. Again plunge a glowing splinter into the test tube. What happens this time? Now use a splinter to scrape together some of the silvery material in the test tube. Pour it into the small dish. What is the material? Do you think mercuric oxide is an element or a compound? Explain your answer.

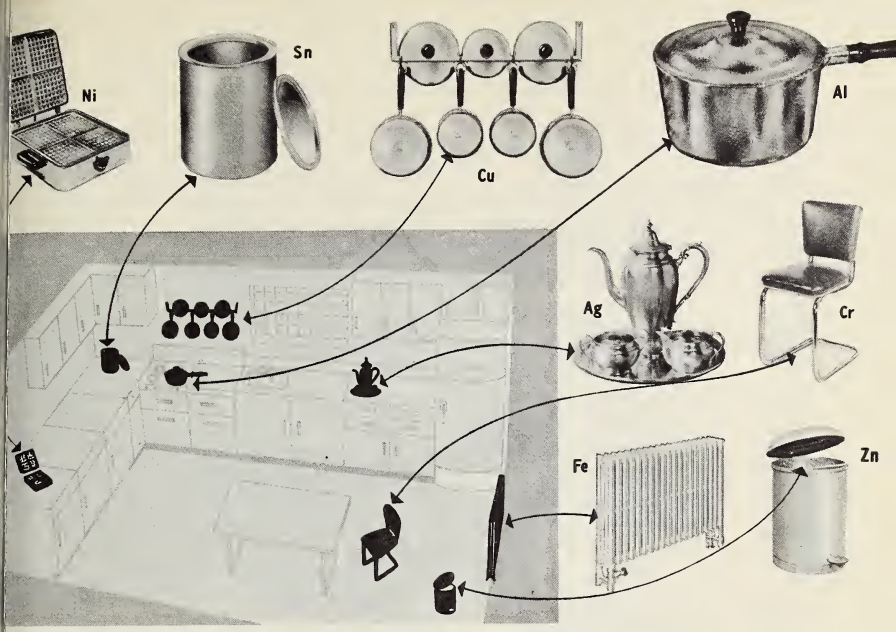
The red powder was changed into two materials. You could see the silvery-colored material, but you could not see the other material. Yet you knew it was there because it made the glowing wood splinter burst into flame. You may have recognized the silvery-colored material. It is mercury. The material that made the glowing splinter catch fire is a colorless, odorless, tasteless gas called oxygen. Chemists can prove that the red powder is a compound made of mercury and oxygen, which are elements. If chemists heat mercury and oxygen together for a long time, the mercury finally disappears. Some of the oxygen is used up, too. In their place is the red powder, mercuric oxide. The two elements, mercury and oxygen, have joined together, or combined, to form a compound.

You cannot see any of the elements in a compound. If you grind mercuric oxide into the finest powder and then look at it under the most powerful microscope, you cannot see any silvery liquid. Water is also a compound. It is made of two elements that are gases, hydrogen and oxygen. You cannot see these gases, and you cannot smell or taste them. But scientists can take water apart and get hydrogen and oxygen. They can also make hydrogen and oxygen combine to produce water. So you cannot tell whether a material is an element or a compound just by looking at it. And you cannot tell by looking at a compound what elements it contains.

SELF-TESTING EXERCISES

1 What is an element? Give some examples of elements.
2 How is a compound related to an element?
3 What do we mean when we say that elements are building blocks of other materials?
4 Can you tell what elements are in a compound by looking at it? Give an example to explain your answer.

If the circles represent molecules of the materials, which ones are elements? Which ones are compounds? How do you know?



Use the table on page 150 to find out what elements are in use in this kitchen. Look around you at home and at school to find other elements in use.

WHAT ARE SOME COMMON ELEMENTS AND COMPOUNDS? Most elements are solids at ordinary temperatures. Some of these are iron, carbon, copper, lead, nickel, aluminum, silver, sulphur, gold, zinc, and tin. The element mercury is a liquid at ordinary temperatures. It does not become a solid until it is cooled to 38° below zero F. Elements such as hydrogen, oxygen, helium, nitrogen, and chlorine are gases at ordinary temperatures.

It would be interesting to make a collection of the different elements, but you would find that samples of many of them are hard to get. Some elements are rare, and others are usually found in compounds. The table on page 150 lists some useful elements with their characteristics and uses. After each element named in the first column, you will find in the next column the *symbol,* or abbreviation, for the element. Instead of writing the whole word, chemists use one or two letters to stand for the element.

The table on page 151 lists some common compounds. It also gives the *formula,* or abbreviation, for each of the compounds. Notice that each formula contains two or more symbols. You

Some useful elements

Name	Symbol	Description	Uses (alone or in compounds)
Aluminum	Al	Light, silver-colored metal	Kitchen pans, airplane parts
Argon	A	Colorless, odorless gas	Electric-light bulbs
Arsenic	As	Poisonous, grayish-white powder	Insect powders, small shot
Boron	B	Black crystals	Boric acid, borax
Bromine	Br	Brownish-red liquid	Poison gases, tear gas, ethyl gasoline, photographic film
Calcium	Ca	Silver-white metal	Limestone, quicklime, mortar, bleaching powder
Carbon	C	Black solid or clear crystals	Coal, diamonds, pencils, ink
Chlorine	Cl	Poisonous, greenish-yellow gas	Germ killer, bleaching compounds, table salt
Chromium	Cr	Silver-white metal	Rustproof plating, stainless steel
Copper	Cu	Reddish-brown metal	Coins, electric wires, kitchen pans
Fluorine	F	Poisonous, pale-yellow gas	Insect powders, etching glass, preventing tooth decay
Gold	Au	Yellow metal	Jewelry, filling teeth
Helium	He	Light, colorless gas	Inflating balloons
Hydrogen	H	Light, colorless gas	Fuel, cutting and welding metals, synthetic fats
Iodine	I	Gray solid or purplish-black crystals	Germ killer, medicines
Iron	Fe	Silver-white metal	Buildings, steel, magnets
Lead	Pb	Soft, bluish-white metal	Paint, pipes, solder, shot, ethyl gasoline
Magnesium	Mg	Light, silver-colored metal	Airplane parts, signal flares, medicines
Manganese	Mn	Grayish-white metal	Dry cells, steel, black paint, glass
Mercury	Hg	Silver-colored, liquid metal	Thermometers, barometers, filling teeth
Neon	Ne	Colorless gas	Advertising signs
Nickel	Ni	Hard, silver-white metal	Coins, plating other metals
Nitrogen	N	Colorless gas	Fertilizers, explosives, ammonia
Oxygen	O	Colorless gas	Breathing, burning, cutting and welding metal
Phosphorus	P	Waxy-yellow solid or reddish powder	Matches, rat poison
Platinum	Pt	Soft, silver-white metal	Jewelry, chemical apparatus
Potassium	K	Waxy, silver-white metal	Gunpowder, fertilizers, soap
Radium	Ra	Silver-white metal	Medicine, luminous paint
Silicon	Si	Brown powder or gray crystals	Glass, grinding stones
Silver	Ag	Soft, white metal	Coins, jewelry, tableware, mirrors
Sodium	Na	Waxy, silver-white metal	Table salt, baking soda, lye, soap
Sulphur	S	Yellow solid	Matches, gunpowder, fireworks, dyes
Tin	Sn	Soft, white metal	Tin foil, plating, solder
Titanium	Ti	Brittle, silver-white metal	Steel, cutting tools, paint, smoke screens
Tungsten	W	Heavy, silver-white metal	Electric-light filaments, tools
Uranium	U	Heavy, hard, white metal	Atomic energy
Zinc	Zn	Bluish-white metal	Dry cells, coating on galvanized iron

Some common compounds

Common name	Chemical name	Formula	Uses
Alcohol, grain	Ethyl alcohol	C_2H_5OH	Solvent, antifreeze
Alcohol, wood	Methyl alcohol	CH_3OH	Solvent, antifreeze
Alum	Sodium aluminum sulphate	$NaAl(SO_4)_2$	Baking powder, medicine, dyes
Ammonia water	Ammonium hydroxide	NH_4OH	Household cleaning
Baking soda	Sodium bicarbonate	$NaHCO_3$	Baking, fire extinguishers, medicines
Blue vitriol	Copper sulphate	$CuSO_4$	Killing fungi, copper plating
Borax	Sodium tetraborate	$Na_2B_4O_7$	Antiseptic, washing, preserving foods
Carbolic acid	Phenol	C_6H_6O	Disinfectant, antiseptic
Carbon tetrachloride	Tetrachlormethane	CCl_4	Cleaning fluid, fire extinguishers
Chile saltpeter	Sodium nitrate	$NaNO_3$	Fertilizers, explosives
Chloroform	Trichlormethane	$CHCl_3$	Anesthetic, solvent
Corn syrup	Glucose, dextrose	$C_6H_{12}O_6$	Making candy, preserving fruits
Cream of tartar	Potassium hydrogen tartrate	$HKC_4H_4O_6$	Cooking, in baking powder
Dry ice	Carbon dioxide (solid)	CO_2	Refrigeration
Glycerine	Glycerol	$C_3H_5(OH)_3$	Lotions, antifreeze, explosives
Gypsum	Calcium sulphate	$CaSO_4 \cdot 2H_2O$	Fertilizer, making plaster of Paris, insulation, in blackboard crayon
Limestone	Calcium carbonate	$CaCO_3$	Building material, fertilizers, refining iron
Limewater	Calcium hydroxide (solution)	$Ca(OH)_2$	Making mortar and bleaching powder, water softening, removing hair from hides
Lye or caustic soda	Sodium hydroxide	$NaOH$	Cleaning, making soap
Moth balls	Naphthalene	$C_{10}H_8$	Repelling clothes moths and other insects
Muriatic acid	Hydrochloric acid	HCl	Manufacturing chemicals, cleaning metals
Oil of vitriol	Sulphuric acid	H_2SO_4	Explosives, fertilizers, chemical manufacturing
Peroxide	Hydrogen peroxide	H_2O_2	Bleaching, antiseptic
Plaster of Paris	Calcium sulphate	$(CaSO_4)_2 \cdot H_2O$	Molds and casts, plastering
Potash	Potassium carbonate	KCO_3	Fertilizers, soap
Prestone	Ethylene glycol	$(C_2H_4(OH)_2)$	Antifreeze
Quicklime	Calcium oxide	CaO	Mortar
Sal ammoniac	Ammonium chloride	NH_4Cl	Dry cells, Soldering metals
Sand, silica, or quartz	Silicon dioxide	SiO_2	Building, glass
Soap	Sodium stearate	$C_{17}H_{35}COONa$	Washing
Sugar, cane or beet	Sucrose	$C_{12}H_{22}O_{11}$	Food
Table salt	Sodium chloride	$NaCl$	Food, preserving food, chemical manufacturing
Vinegar	Acetic acid (with water)	CH_3COOH	Flavoring, pickling foods
Washing soda	Sodium carbonate	Na_2CO_3	Washing, glass

In the table on page 151, find the compounds represented in this picture by chemical formulas. Try to find compounds like these that are used in your home. What elements are in these compounds?

might expect this because every compound is made of two or more elements. In some of these formulas, there are little numbers. Chemists use these numbers to tell how much of each element it takes to make the compound. For example, the formula for water is H_2O. This means that water is made of two parts of hydrogen and one part of oxygen. So from this table you can tell what elements are in each compound and also how many parts of each element it takes to make the compound. For example, the chemical name for table salt is sodium chloride. Its formula is NaCl. Na stands for sodium, and Cl stands for chlorine. In Experiment 1 you found that mercuric oxide contains mercury and oxygen. The chemical formula for mercuric oxide is HgO. Hg stands for mercury, and O stands for oxygen.

SELF-TESTING EXERCISES

1 Why is it hard to get samples of some of the elements?
2 Why do chemists use symbols for the elements?
3 State two things that a formula tells a chemist about a compound. Use a formula from the table on page 151 as an example.

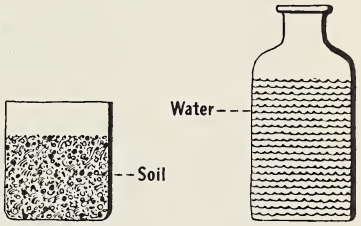
WHAT ARE MIXTURES? You have learned that all the materials in the world are made of elements. Some materials contain only one element. In other materials the elements are combined into a compound. If a material contains only one element or only one compound, chemists call the material pure. Iron and iron rust are pure materials. Iron is a pure element, and iron rust is a pure compound. Sugar is also a pure compound. Air and milk are not pure materials. They are neither pure elements nor pure compounds. They are mixtures of elements and compounds. You can learn more about a mixture by doing Experiment 2.

Experiment 2 Is soil a mixture?

1 Pour the soil into the water and shake the bottle thoroughly. Then let it stand until the soil settles.

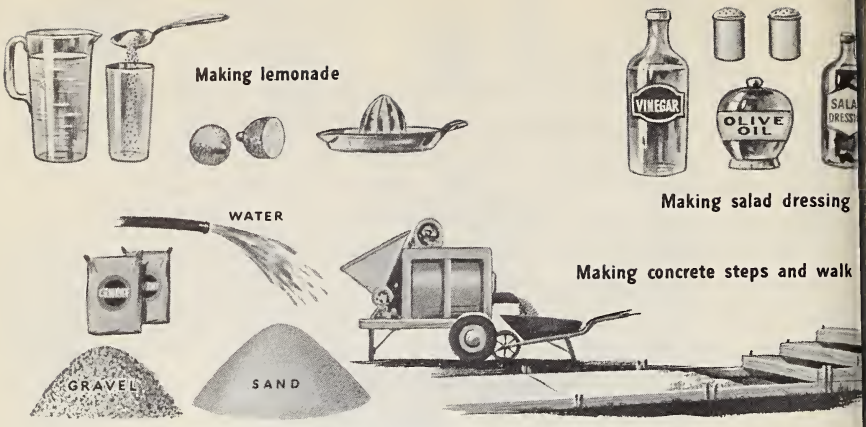
2 What materials do you see in the bottle?

3 Is soil a compound or a mixture? Give reasons for your answer.



When you mixed the soil with water and let it stand, you saw some particles settle to the bottom and others float around in the water. There were large and small particles of sand, clay, and decayed plant and animal materials. When these materials make soil, they are still the same materials. No new material is formed. So soil is not a compound. It is a mixture.

Air is also a mixture. It is a mixture of gases. Air contains large amounts of the elements nitrogen and oxygen. These are mixed with small amounts of water vapor and carbon dioxide, which are compounds. Air also contains very small amounts of other gases. Milk is a mixture of water, fats, sugar, and other materials. Wood, paper, cloth, glass, and even your own body are mixtures of elements and compounds.



Are mixtures or compounds being made? How do you know?

SELF-TESTING EXERCISES

1 What is meant by a pure material?
2 What is a mixture made of?
3 Name three common mixtures and tell what materials are in each.

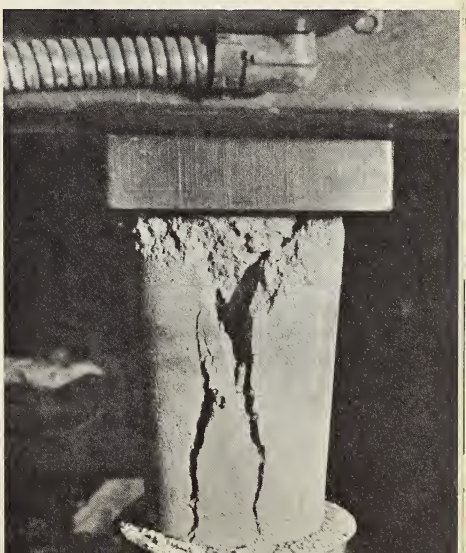
PROBLEMS TO SOLVE

1 What elements in the table on page 150 have you seen or used? What other elements in the table have you heard about?
2 The table on page 151 lists eight compounds that contain sodium. How do these compounds help you understand why so many materials can be made from less than 100 elements?
3 When someone tells you that gold is an element, what do you immediately know about gold?
4 Iron rust is a compound. What does this tell you about rust?
5 Refer to the tables on pages 150 and 151. Then write the names of the elements in each of these compounds: alcohol, baking soda, limestone, sugar, table salt.
6 When you stir sugar and sand together, do you make a mixture or a compound? Explain why you think your answer is right.
7 Mercuric oxide separates into its elements when it is heated. Is it correct to say that all compounds can be separated into their elements by heating them? Give a reason for your answer.
8 Suppose that you dissolve salt in water. Does this make a compound of salt and water? Explain your answer.

How can we recognize a chemical change?

2

How do we tell one material from another? You have learned that chemists have found over 500,000 different materials. If you give a chemist a sample of any one of these materials, he can find out what it is. How do you suppose chemists can tell all these materials apart? Of course even a person who is not a chemist can recognize some of the common materials. If someone hands you a piece of clean copper and a piece of clean aluminum, you can tell them apart instantly. You know the copper by its reddish color and the aluminum by its silvery color. We recognize things in various ways: by noticing their state (solid, liquid, or gas) at ordinary temperatures; by looking at their color and general appearance; by lifting them to feel their weight; and by smelling, touching, and tasting them. *(Never taste materials you do not know. They may be poisonous.)* By making these observations, we can discover the characteristics of each material. When scientists are talking about materials, they use the word *properties* instead of characteristics. Materials have both physical properties and chemical properties. Some of the physical properties of water are as follows: It is a liquid at ordinary temperatures. It is transparent and colorless. At sea level, water boils at 212° F. and freezes at 32° F. It weighs 62.4 pounds per cubic foot.



Before building a road, many highway departments test certain physical properties of the materials to be used. Here a test is being made to see how much weight a sample of concrete can stand before it cracks. What physical property is being tested?

Another way of telling the difference between some materials is by their chemical properties. A piece of ordinary paper and a piece of asbestos paper may look much alike. If you throw them both into a fire, the ordinary paper will burn. The asbestos paper will not. We often recognize a piece of iron or steel because it rusts easily. Properties like these are chemical properties. Some of the chemical properties of water are as follows: It is not easily changed chemically. It does not burn, and it does not help other materials burn. It can be changed into hydrogen and oxygen with an electric current. It helps make iron rust.

To tell the difference between hundreds of thousands of materials, chemists use many tests. One of the easiest chemical tests is called the flame test. To make this test, a chemist heats a little of the unknown material on a clean platinum wire in a blue gas flame. Certain elements give colors that are not like those given by any other elements. Sodium gives an orange-yellow flame, calcium a brick-red flame, and copper a blue-green flame. This test is only a beginning one. It gives the chemist a hint of what elements the material may contain. You can find out how chemists use the flame test by doing Experiment 3.

Experiment **3** How do chemists use the flame test?

What you need: Pliers; 1 foot of small iron wire; dilute and concentrated hydrochloric acid; gas burner (or alcohol lamp); matches; four small squares of glass; sodium chloride (table salt); very pure potassium nitrate; very pure calcium chloride, copper sulphate.

What you do: Use the pliers to bend one end of the wire into a loop about one eighth of an inch across. Clean this end of the wire by dipping it into dilute hydrochloric acid and then holding it in the blue flame of a gas burner until it does not noticeably change the color of the flame.

Now pour a little sodium chloride on a glass square and moisten it with concentrated hydrochloric acid. HANDLE THE CONCENTRATED ACID ONLY WHEN THE TEACHER IS WITH YOU. Dip the clean wire loop into the moistened sodium chloride and then heat it in the edge of the blue flame. What color is the flame now? This color is caused by the element sodium in the sodium chloride.

Repeat the flame test, using each of these materials: potassium nitrate, calcium chloride, and copper sulphate. Before testing each material, cut off the used wire loop and make a new one. What color does each material give the flame? The color is caused by the element whose name comes first in the name of the compound.

You can now understand another use of the spectroscope (page 28). Scientists use a spectroscope to find out what elements a material contains. First, they heat the material hot enough to make its vapor glow. This glow is then spread out into separate bands of colors by the spectroscope. These bands of colors tell what elements are in the material. If a scientist sees orange and yellow bands in a certain place, he knows that they mean the element sodium. Certain blue and green bands mean copper, and so on.

You have already used another test for a material. In the experiment on page 90, you used an iodine solution to test for starch. You found that iodine turns starch blue or blue-black. No material but starch will turn this color when it is treated with iodine. So chemists know that if an unknown material turns blue or blue-black when iodine is added, the material must have starch in it. Do Experiment 4 to find out how chemists test materials for starch.

Experiment 4 How do chemists test materials for starch?

What you need: Foods such as potato, tomato, carrot, or other vegetables, apple, banana, bread, sugar, etc.; several small porcelain or glass dishes; medicine dropper; dilute iodine solution. (See page 90 for directions.)

What you do: Put a small piece of the food to be tested into a dish. Add a few drops of the iodine solution to the food. Which foods contain starch? Which foods do not have starch in them? How do you know?

Vinegar and lemon juice belong to a group of materials known as acids. Vinegar is a solution of acetic acid in water, and lemon juice has citric acid in it. You can be fairly sure that anything with a sour taste contains an acid, but never taste a material without knowing what it is. The best way to test for acids is to use litmus paper. Litmus paper is made by soaking white paper in a dye. A chemist knows that anything with an acid in it will turn blue litmus paper red. But acids will not change the color of red litmus paper.

Litmus paper is also used as a test for a group of materials called *bases,* or *alkalis* (al′ kə līz). Lye, limewater, and ammonia water belong to this group. Lye is used to make soap and sometimes to remove paint. Limewater is often given to people who need calcium for their bones. Ammonia water is commonly used for cleaning. Although you can often recognize bases by their bitter taste, it is much safer and more accurate to use litmus paper to test them. Bases turn red litmus paper blue, but they do not change the color of blue litmus paper.

When acids and bases act on each other, they form materials that chemists call *salts.* Table salt is just one kind of chemical salt. When an acid and a base act on each other to form a salt, we say that they *neutralize* each other. Salts are neither acids nor bases. So we say that they are *neutral.* You may have seen your father spreading lime on the garden or the lawn. He does this because he has probably found out that the soil is too acid for plants to grow well. Lime is a base, and it will neutralize the acid in the soil. By using the litmus test, a chemist can tell whether an unknown material is an acid or a base. If it is not an acid or a base, it is neutral. You can learn how to use the litmus test in Experiment 5.

Experiment **5** How do chemists tell whether a solution contains an acid or a base?

What you need: Distilled water; vinegar; lemon juice; very dilute hydrochloric acid; very dilute lye (sodium hydroxide) solution; ammonia water (ammonium-hydroxide solution); limewater (calcium-hydroxide solution); table-salt solution; washing-soda solution; nine small porcelain or glass dishes; pieces of red and blue litmus paper.

What you do: Pour a little of each solution into a separate dish. Test each solution first with red litmus paper and then with blue litmus paper. Notice whether any change takes place in the litmus paper. Make a record of the results of each test. Which solutions are acids? Which ones are bases? Are any of the solutions neutral?

Which kind of property does each picture illustrate?

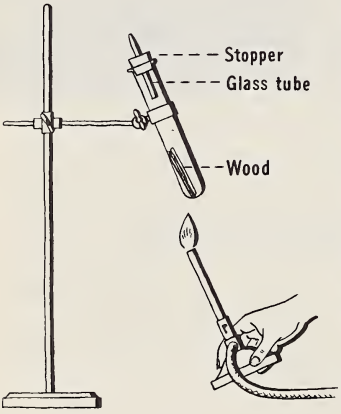
SELF-TESTING EXERCISES

1 How does a chemist discover the properties of a material?
2 Why do chemists use the flame test?
3 How can you find out whether a material is an acid, a base, or neutral?
4 What tests could you use to find out what an unknown material is? Tell how you would make the tests.
5 How can you test a food to find out whether it contains starch?

WHAT HAPPENS IN A CHEMICAL CHANGE? If you have ever eaten a piece of bread, lighted a fire, taken a photograph, made a cake, or dyed a dress, you brought about a chemical change. You have seen the results of many other chemical changes. When food spoils, fountain-pen ink changes color, soft concrete becomes hard, leaves on trees change color, or pieces of wood decay, chemical changes are going on. In Experiment 1 you saw mercuric oxide change into mercury and oxygen. And you learned that oxygen and hydrogen can combine to form water. All these changes in materials are chemical changes.

To find out what happens during a chemical change, you can observe the properties of a material before and after it changes. Wood is white or yellowish-white, can be cut with a knife or saw, has a certain weight, and can burn with a flame. These are some of the properties of wood before a chemical change takes place. Now do Experiment 6 to find out what happens to wood when it is heated.

Experiment **6** What happens when wood is heated?



1 What do you need to do this experiment?

2 Heat the test tube strongly, moving the flame around so that all of the wood is heated but the glass does not melt.

3 What comes out of the test tube? Will it burn? What do you see in the test tube?

4 Keep heating the wood until no more gas is made.

5 What do you see on the side of the test tube? What is left on the bottom of the test tube?

6 Did a chemical change take place when wood was heated? Why do you think so?

Heating changes wood into other materials. First, whitish fumes are given off. These fumes are a mixture of carbon monoxide, carbon dioxide, hydrogen, and other gases. (Some of these gases may condense to form a black, sticky liquid.) After all the gases are driven off, a black solid called charcoal is left. This black material is mostly the element carbon. None of these materials has the same properties as the wood. The wood is no longer wood, but it has changed into different materials. This is what always happens when a chemical change takes place. One

material is changed into another material with different properties. Or it may be changed into several materials that are all different from the first material. Now do Experiment 7 to find out what happens when iron and sulphur are heated together.

Experiment 7 What happens when iron and sulphur are heated together?

1 Mix the iron powder and the powdered sulphur thoroughly. Divide the mixture into three parts.

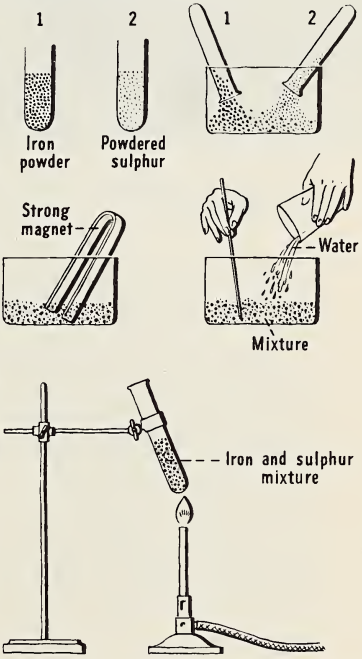
2 Hold a magnet close to one part of the mixture. What happens? Has a chemical change taken place? Explain your answer.

3 Add water to another part of the mixture and stir it thoroughly. Then let it stand for a while. What happens? Did a chemical change take place? How do you know?

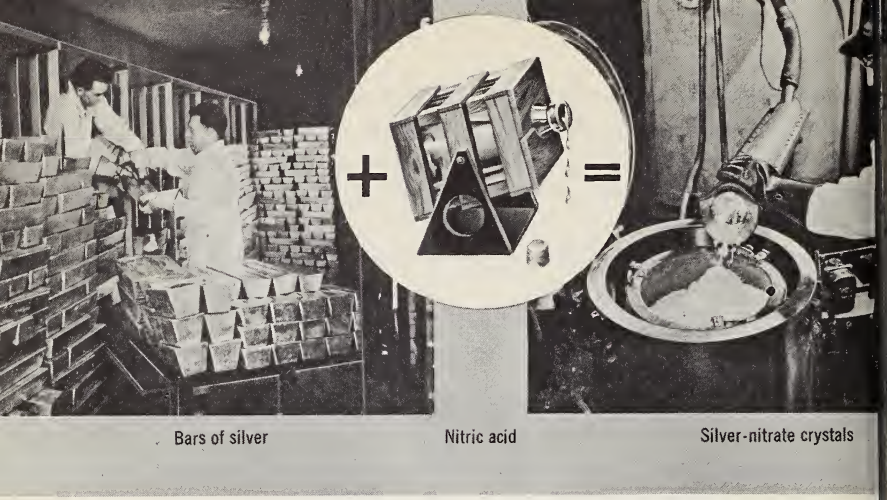
4 Heat the third part of the mixture of iron and sulphur in a test tube until a red glow spreads all through it. When the tube is cool, break it and take out the material. How can you test the material to find out whether it is still a mixture of iron and sulphur?

5 Test the material. What do your results show?

6 Answer the question of the experiment. Give reasons for your answer.



When iron and sulphur are just mixed together, they can be easily separated by using a magnet or by putting the mixture in water. In water, the heavy iron particles settle quickly to the bottom. Then the lighter sulphur particles settle on top of the iron. But no change takes place in the iron and sulphur. We know this



Does a chemical change take place when silver-nitrate crystals are made from silver and nitric acid? How do you know?

because the properties of the two materials are just the same as they were before the materials were mixed together.

After the iron and sulphur particles were heated together, you saw that they could no longer be separated by using a magnet or by mixing them with water. A chemical change had taken place. The iron and sulphur combined to form a different material. This material is iron sulphide, a compound of iron and sulphur. It is not like iron or sulphur. As a result of the chemical change, a material with different properties was formed. All chemical changes are alike in this way: The material or materials that are formed have different properties from the materials you started with.

SELF-TESTING EXERCISES

1 How can you tell when a chemical change has taken place?

2 **a** How do you know that a chemical change took place when wood was heated?

b When iron and sulphur were heated?

c When mercuric oxide was heated?

3 How are all chemical changes alike?

When sulphuric acid is poured over sugar, the acid removes water (hydrogen and oxygen) from the sugar, leaving black carbon. The heat and water that are produced form steam, which puffs the carbon into a spongy mass. What kinds of changes have taken place? How do you know?

PROBLEMS TO SOLVE

1 Tell which of these are chemical changes and which are physical changes.

a Butter melts when it is heated.

b Matches light when rubbed on a rough surface.

c Water freezes when cooled below 32° F.

d Rock is crushed into small pieces.

e Green leaves become yellow when they are kept in the dark.

f Meat decays if it is not kept properly.

g Gasoline evaporates if left in an open dish.

h A green coating forms on copper roofs.

i Aluminum may be pressed into thin sheets.

j A firecracker explodes when it is lighted.

k Photographic films are spoiled if exposed to light.

l Camphor dissolves in alcohol.

m The whites of eggs become fluffy when beaten.

n Colored clothes often fade when washed in water containing ammonia.

o A silver spoon often turns black after it touches egg yolk.

p Straw hats that have become yellow are made whiter with lemon juice.

2 Materials need oxygen in order to burn. Water is made of hydrogen and oxygen, but materials will not burn in water. Explain.

3 Iron rust contains oxygen and iron. Why can you not use a magnet to separate the iron from the oxygen?

4 When baking soda is mixed with lemon juice, the mixture foams. Is this a chemical change? Explain.

5 Is the distillation of water a chemical change? Explain.

6 Make a list of some chemical changes that are going on around you. Then explain how you know that each one is a chemical change.

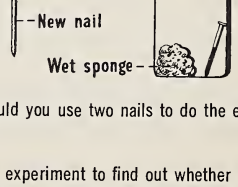
3

How can we control chemical changes?

You have probably seen many labels like these on boxes or bottles: "Keep in a cool, dark place." "Do not use near an open flame." "Keep in a dry place." And perhaps you have seen this warning on a box of camera film: "Do not open in the light." Why do you suppose these statements are printed on the labels? They are put there so that you will know how to keep the materials from spoiling. If you do not follow the directions, harmful chemical changes will take place.

Chemists are interested in changing materials into other materials that we need. They are also interested in preventing changes in the materials that we want to keep as they are. Of course, elements cannot combine until they are brought together. Iron sulphide cannot be produced until iron and sulphur are brought together. But just bringing materials together is usually not enough to cause a chemical change. Iron and sulphur must be heated before they will form iron sulphide. Yet the chemical change cannot take place at all unless the materials are brought together. From this you can understand that some chemical changes can be prevented by keeping certain materials away from each other. Do Experiment 8 to find out how we can keep iron from rusting.

Experiment 8 How can iron be kept from rusting?



1 What do you need to do this experiment?

2 How can you use these materials to find out whether paint keeps iron from rusting?

3 Why is half the nail painted and the other half not painted?

4 Leave the iron nail in the closed jar with a wet sponge for several days. What happens?

5 How could you use two nails to do the experiment?

6 Plan an experiment to find out whether oil keeps iron from rusting. Try the experiment. What happens?

When air touches moist iron, oxygen in the air will combine with the iron and form iron oxide, or rust. A chemist knows this. So he looks for something to keep the oxygen in the air from touching the iron. He must use a material that will not combine with the iron. Paint does not change the iron, and it does keep away the oxygen. Now you can understand why bridges, fences, and other objects made of iron are painted. Oil acts in much the same way as paint in preventing chemical changes in iron. Tools that are not often used should be wiped with an oily rag when they are put away.

Scientists have learned that dissolving some materials will cause a chemical change. Two materials may be mixed together, but no chemical change will take place until a liquid is added. By doing Experiment 9, you can find out what effect dissolving has on some chemical changes.

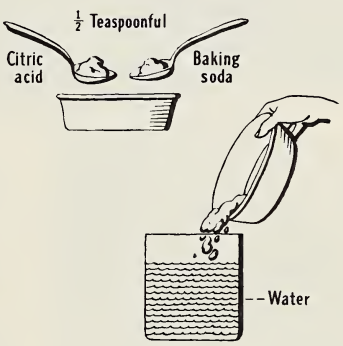
Experiment 9 What effect does dissolving have on some chemical changes?

1 Mix some citric-acid crystals and baking soda in a dry dish. Does a chemical change take place? Why do you think so?

2 Add this mixture to water. Does a chemical change take place now? How can you tell?

3 What made the difference between your results in 1 and 2?

4 What do you think would happen if you mixed the citric-acid crystals and the baking soda in a wet dish? Try it and see what happens.



You saw that when citric-acid crystals and baking soda are mixed and kept dry, nothing happens. But when these materials are mixed with water, a gas (carbon dioxide) is made. This shows that a chemical change has taken place. Baking powder works

The man in the center is dipping a piece of metal into a plastic material that will cover it with a thin coating. How will this help protect the metal? The man at the bottom is putting fish into a refrigerator. How does this prevent a chemical change? How are the people in the other pictures protecting materials from chemical change? Look for as many examples like these as you can find.

in this same way. As long as the baking soda and other compounds in baking powder are dry, no change takes place. But when you stir them into moist cake batter or biscuit dough, a chemical change takes place. Bubbles of carbon dioxide are produced, and small amounts of other compounds are left in the cake or biscuits. Even the moisture in the air will cause a chemical change in baking powder. So you can bring about some chemical changes by dissolving materials. You can also prevent these chemical changes by keeping the materials dry.

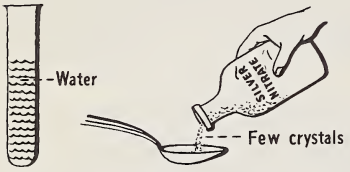
You have already seen that you can make some chemical changes take place by heating materials. When iron and sulphur were mixed together and then heated, iron sulphide was produced. Heat is also needed to light a match. When the match is rubbed on a rough surface, there is friction between the two rubbing surfaces. This friction heats the match, and the heat makes a chemical change take place. The materials on the match combine with the oxygen in the air and begin to burn. If you touch a match head to a hot stove, the match will light without rubbing because the heat is already there in the stove.

Many chemical changes will not take place at all unless the materials are heated to a high temperature. For example, one kind of iron ore is a compound of iron and oxygen (Fe_2O_3). The iron ore also contains some impurities. To get iron, the impurities and the oxygen must be removed from the ore. To do this, limestone and coke are mixed with iron ore. When these materials are just mixed together, nothing happens. The mixture must be heated to a high temperature in a large blast furnace. Then the limestone removes the impurities, and the coke takes the oxygen away from the iron ore. Finally, the iron alone is left.

Heat can also cause chemical changes that we do not want. If a bottle is labeled "Keep in a cool place," you know that a chemical change may take place if the material in the bottle gets too warm. To prevent chemical changes caused by heat, materials we do not want changed in this way must be kept cool. Milk will sour, and meats and vegetables will spoil very quickly if they are left in a warm room. To prevent these chemical changes, many foods are kept cool in a refrigerator.

Another way of making some chemical changes take place is to use light. Experiment 10 will show you what effect light has on some chemical changes.

Experiment 10 What effect does light have on some chemical changes?



1 Dissolve the silver nitrate in water. Watch for a chemical change. What happens?

2 Pour half of the silver-nitrate solution into another test tube. Put one test tube in bright sunlight and the other one in a dark place.

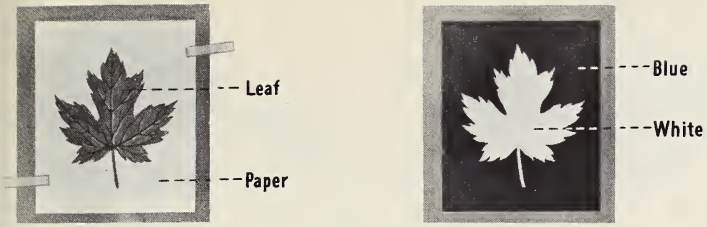
3 In which test tube does a chemical change take place? How do you know?

4 Why did you use two test tubes of the solution in this experiment?

5 What can you do now to show that the chemical change was caused by light? Try it and see what happens.

When silver-nitrate solution is brought into a strong light, a chemical change takes place. You can tell this because the solution turns dark. A similar change takes place when you take a picture with a camera. The film has a chemical on it that is easily changed by light. When you open the shutter of the camera for an instant, light strikes the film and starts a chemical change in it. This change is completed when the film is developed. If light gets into the camera before you are ready to take the picture, the chemical change takes place before you want it. Then the film is spoiled.

Perhaps you have seen a blueprint. You probably remember that the paper was blue, but the lines and writing on the paper were white. Maybe you thought white ink had been used on blue paper. Actually, the blue parts are the result of a chemical change. White paper is coated with a chemical solution. The drawing that is to appear on the blueprint is made on a piece of thin paper or cloth. This paper or cloth is placed on top of the



You can see how blueprints are made if you make a print of a leaf. When the paper with the leaf on it is put in the sunlight and then washed with water, the part where the leaf was stays white. The part of the paper on which the sun could shine turns blue.

blueprint paper, and they are put in a strong light. The blueprint paper is then washed in clear water. The parts of the paper that were in the light turn blue, but the rest of the paper stays white. So the dark lines that were drawn on the thin paper or cloth now appear on the blueprint paper as white lines.

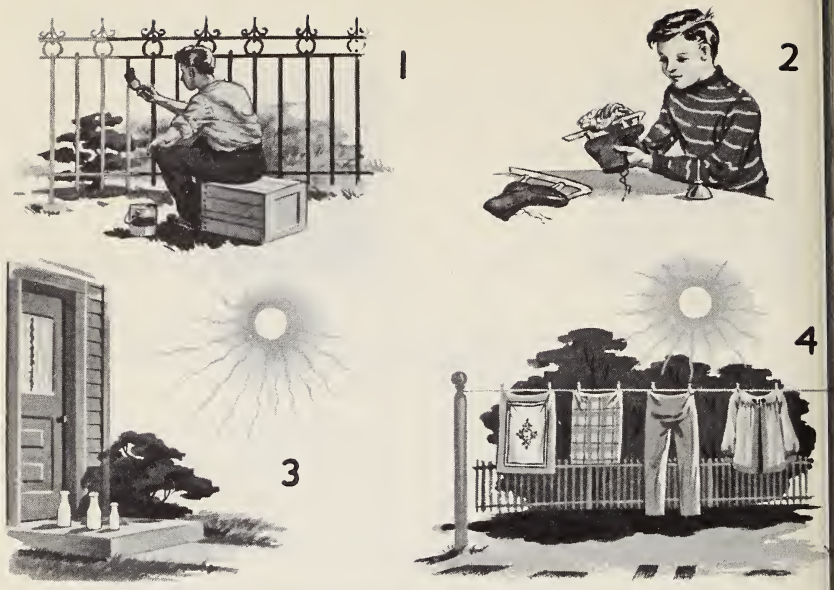
You can understand now why some bottles and boxes are labeled "Keep in a dark place." Light would cause a harmful chemical change to take place in these materials. Some chemicals are even put in dark-colored bottles to keep out the light. Have you ever noticed that hydrogen peroxide (H_2O_2) is sold in brown bottles? When hydrogen peroxide is left in a strong light, it quickly separates into oxygen and water.

SELF-TESTING EXERCISES

1 Describe four ways of making chemical changes take place.
2 Describe four ways of preventing chemical changes.
3 How does paint or oil keep iron objects from rusting?
4 How are impurities and oxygen removed from iron ore?
5 How are the bubbles in biscuit dough or cake batter the result of chemical change?
6 What happens when hydrogen peroxide is left in a strong light?

PROBLEMS TO SOLVE

1 When a picture is taken off a wall, the wallpaper or paint back of the picture is usually darker or lighter than the rest of the wall. Explain.



In Pictures 1 and 2, what is being done to prevent chemical change? How will this be done? In Pictures 3 and 4, what harmful chemical changes might take place? How could these changes be prevented?

2 The backs of books that have been kept in bookcases for several years are not so brightly colored as the sides. Explain.

3 You can buy prepared pancake flour in a store. Why do you suppose it must be kept dry?

4 Why does food turn black if it is kept on a hot stove too long?

5 Carbon disulphide is a chemical with a bad odor that is often used in grain bins to kill insects. Why do the directions say, "Do not bring near an open flame"?

6 Charcoal is made by heating wood in airtight ovens. What would happen to the wood if air got in as the wood was being heated?

7 White clothes dried in the sun are whiter than if they are dried in the shade. Explain.

8 Why do doctors often keep medicines in refrigerators?

9 In Experiment 8, why was a wet sponge put in the jar with the iron?

10 Rugs and furniture coverings often fade. What is one thing that can be done to keep them from fading?

11 Why is it a good idea to keep wooden houses painted?

How can we explain chemical changes?

4

WHAT ARE MOLECULES MADE OF? In Unit 4 we used the molecular theory to explain physical changes. Before we can explain chemical changes, you need to learn more about how materials are put together. You already know that a material, such as water, is made of molecules. According to the molecular theory, a molecule of any material is the smallest particle of that material which can exist. For example, a molecule of water is the smallest particle of water that there can be. But the formula for water (H_2O) shows that each molecule of water is made up of two particles of the element hydrogen and one particle of the element oxygen. So scientists believe that there must be other particles of matter besides molecules.

To explain what molecules are made of, scientists use the atomic theory. According to this theory, all molecules are made of small particles called *atoms* (at′əmz). An atom is the smallest particle of an element that can exist. For example, an atom of iron (Fe) is the smallest particle of iron that there can be. No one has ever seen an atom, and probably no one ever will. But the atomic theory explains so many facts about matter that we talk about atoms just as though we could see them.

A molecule of an element is made of one or more atoms of the same kind. Most elements have only one atom in a molecule. A molecule of iron is made of only one atom, and so is a molecule of sulphur. But some elements that are gases have two atoms in a molecule. Elements such as hydrogen, oxygen, nitrogen, and chlorine have two atoms in a molecule. The formula for a molecule of hydrogen is H_2, oxygen O_2, nitrogen N_2, and chlorine Cl_2. Helium is a gas that has only one atom in a molecule, and so its formula is just He.

You know that every compound is made of two or more elements. So a molecule of any compound must be made of two or more kinds of atoms. If there are three kinds of elements in a compound, there are three kinds of atoms in each molecule of that compound. For example, the formula for calcium carbonate,

the main compound in limestone, is $CaCO_3$. This shows that each molecule of calcium carbonate contains one atom of calcium (Ca), one atom of carbon (C), and three atoms of oxygen (O_3). As you can see, the formula for a compound shows not only what kinds of atoms but also how many atoms of each kind there are in a molecule of a compound.

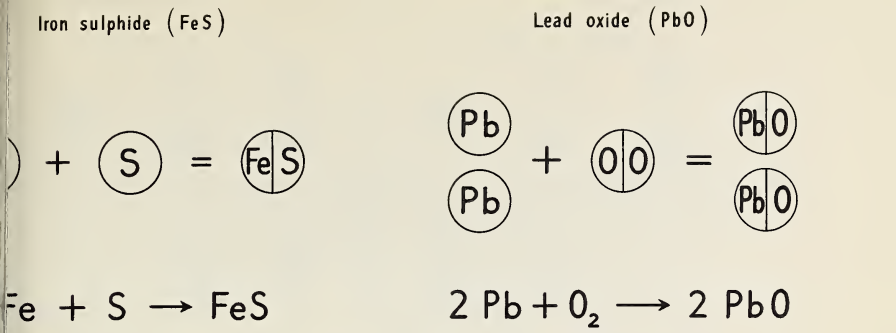
SELF-TESTING EXERCISES

1 **a** What is the name for the smallest particle of a compound?
  b What is the name for the smallest particle of an element?
2 **a** How is the molecule of a compound like the molecule of an element?
  b How are they different?
3 The formula for cane or beet sugar is $C_{12}H_{22}O_{11}$. What does this show you about each molecule of the compound?

WHAT HAPPENS TO MOLECULES DURING CHEMICAL CHANGES? You remember the chemical change that takes place when iron and sulphur are heated together. The iron and sulphur combine to make a different material, iron sulphide. This kind of chemical change is called *combination*. The rusting of iron is another example of chemical combination. Iron combines with oxygen in the air to form rust, or iron oxide.

We can show what happens to the molecules when iron and sulphur combine by writing out all the words in a sentence: One molecule of iron combines with one molecule of sulphur to form one molecule of iron sulphide. But chemists have a much shorter and simpler way of writing the same thing. As you know, chemists use symbols and formulas instead of writing out the words for elements and compounds. Chemists also use these symbols and formulas to show what happens to molecules during a chemical change. They write down the symbols and formulas in a chemical *equation*. Here is the equation for the chemical combination of iron and sulphur: $Fe + S \rightarrow FeS$.

If you melted some lead in Experiment 4, Unit 4, you noticed that a scum formed on the melted metal. This scum is lead oxide. It is formed when some of the lead combines with oxygen



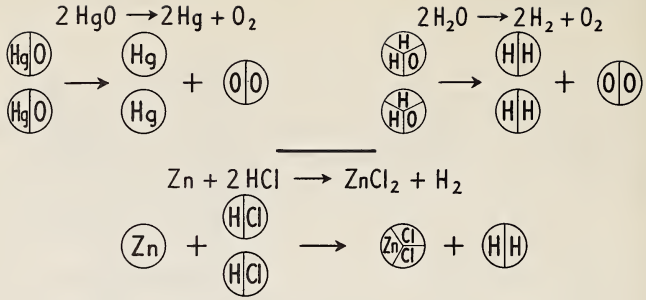
Each circle represents a molecule of an element or a compound. Of course, atoms in molecules do not look like this. But the diagrams will help you understand how elements combine to form compounds.

in the air. There are several compounds of lead and oxygen. This one is called lead monoxide. Its formula is PbO. The chemical combination that takes place when lead is heated in air is shown by the equation: $2Pb + O_2 \rightarrow 2PbO$. This shows that two molecules of lead (2Pb) combine with one molecule of oxygen (O_2) to form two molecules of lead monoxide (2PbO).

You must not get the idea that any two elements can be combined to make a compound. Lead and iron will not combine to form a compound. Neither will copper and gold. Also, some compounds are made of more than two elements. (See the table on page 151.) Chemists have done thousands of experiments to find out which elements can be combined to form compounds. They have also discovered many ways to make elements combine.

Another kind of chemical change is just the opposite of combination. You remember that when the compound mercuric oxide is heated, it changes into two elements, mercury and oxygen. The mercuric oxide separates, or *decomposes,* into mercury and oxygen. This kind of chemical change is called *decomposition.* It starts with a compound, which decomposes into two or more other materials. The decomposition of mercuric oxide is shown by the equation: $2HgO \rightarrow 2Hg + O_2$.

When wood is heated, it decomposes. A great deal of one element, carbon, is left as charcoal. The element hydrogen and several compounds, such as carbon monoxide and carbon dioxide, go into the air as gases. So a material may decompose into ele-



Which diagrams show decomposition? Which diagrams show replacement?

ments or into compounds or into both elements and compounds. Not all compounds can be decomposed by heating them. Water is a compound of hydrogen and oxygen. When water is heated hot enough, it just changes to steam. It does not decompose. If the steam is cooled, it changes back to liquid water again. But water can be decomposed by sending an electric current through it. The decomposition of water is shown by the equation: $2H_2O \rightarrow 2H_2 + O_2$.

You can see another kind of chemical change by doing an experiment. Dip a clean iron nail into a solution of copper sulphate ($CuSO_4$). Hold the nail in the solution for several minutes. When the iron is removed from the copper sulphate, you will see that it is coated with copper. This shows that some of the copper atoms must have been taken away from the copper sulphate. By certain tests, chemists can prove that there is now iron sulphate ($FeSO_4$) in the solution. So some of the iron atoms from the nail must have changed places with some of the copper atoms in the copper sulphate. We say that the iron *replaces* the copper. So this kind of chemical change is called *replacement*. The replacement of copper by iron in the solution is shown by the equation: $Fe + CuSO_4 \rightarrow FeSO_4 + Cu$.

You have learned that there are several kinds of chemical changes. All of them are alike in one way: There is always a change in the molecules of the materials. Atoms are added or taken away or rearranged to make different molecules. Then we have a different material or different materials.

SELF-TESTING EXERCISES

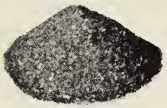
1 What are three kinds of chemical change?
2 What two things does a chemical equation show?
3 Tell what happens to the molecules in each of these chemical changes:
$2H_2+O_2 \rightarrow 2H_2O$ $2HgO \rightarrow 2Hg+O_2$ $Fe+CuSO_4 \rightarrow FeSO_4+Cu$
4 How are all chemical changes alike?

PROBLEMS TO SOLVE

1 Table salt is made of sodium and chlorine. Sodium will cause a sore if placed on your tongue, and chlorine is a poisonous gas. Explain why we can safely use the compound made from these elements.
2 If a candle flame is held close to a piece of glass, carbon forms on the glass. What kind of chemical change has taken place? Tell how you know.
3 A silver fork darkens, or tarnishes, when used with eggs. Is this a chemical change? Explain your answer.
4 When a tree decays, part of it changes to a gas that mixes with the air. Part of it goes back into the ground as minerals. What kind of change is this?

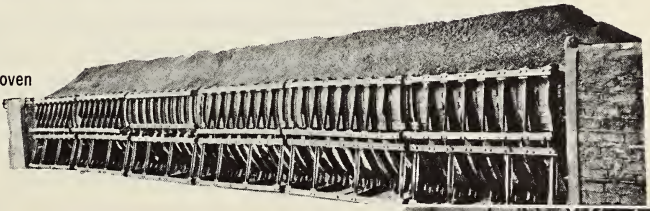
What kind of chemical change takes place when

coke C



and sand SiO_2

are heated in an oven and form silicon carbide SiC



a material hard enough for polishing the hardest metals?

In paint farms like these, paints are exposed to all kinds of weather to see how well they will last. What kinds of changes might take place in the paints? Explain.

5 If a pie is baked too long, the crust turns black. What is the black material? Is the change combination or decomposition? Why?
6 Charcoal disappears when it burns in air. What kind of chemical change takes place? What compound is formed?

SUMMARY EXERCISES

1 Make a list of the big ideas that you learned in this unit. Write them as complete sentences.
2 Show that you know what the following words mean: physical change, chemical change, element, compound, mixture, chemical symbol, chemical formula, properties, atom, chemical equation, combination, decomposition, replacement.

ADDITIONAL ACTIVITIES

1 Collect samples of all the elements that you can get. Put them in test tubes or small bottles. Label each sample with the name of the element and its uses. Then fasten the containers to a large cardboard.
2 Heat some sugar in a test tube. What makes you think that a chemical change takes place? How does the experiment show you that sugar is a compound?
3 Moisten a teaspoonful of fresh quicklime (unslaked lime) with water. Does a chemical change take place? How do you know?
4 Put a tablespoonful of alcohol in a clean saucer. Burn the alcohol and see whether the flame is colored. Now dissolve some boric-acid powder in alcohol. Pour a little of the liquid in a saucer and light it.

What is the color of the flame now? What kind of test is this? Refer to the table on page 150. What element do you think made the flame appear different after the powder was mixed with the alcohol?

5 Put the fresh legbone of a chicken in a strong vinegar solution and let it stay there several days. The bone will get soft enough for you to tie in a knot. Try to find out what happened to the bone to make it soft. Let it dry and ask your friends to tell you how you tied the bone in a knot.

6 Dissolve a pinch of baking soda in a little water and then test the solution with both red and blue litmus paper. Add a few drops of vinegar to the solution and test it again. What happens when the vinegar is added to the baking soda? Is this a chemical change? How do you know?

7 Use some red and blue litmus paper to test some of the chemicals in your home. Find out which ones act as acids, which ones act as bases, and which ones are neutral. The materials you test might include soap, toothpaste, tooth powder, water softeners, cleansers, polishes, fruits, sour milk, and other foods. Mix any dry material with water before you test it. Record your results in a table.

8 Pour a little vinegar into a saucer. Drop a dull copper penny into the vinegar and let it stay a few seconds. What happens? Remove the penny and add a teaspoonful of salt to the vinegar. Put the penny back in the solution. What happens to the color of the penny after the salt is added? Has a chemical change taken place? How do you know?

9 Look around at home and find bottles or boxes that have labels such as those given in the first paragraph on page 164. Make a list of the kinds of labels you find and what is in the box or bottle. Give the reason for each label.

10 Get some silver spoons or forks that have tarnished. Pour some water into a flat aluminum pan and dissolve a few pinches of washing soda in the water. Put the silver in the pan of water and heat it until the water boils. Does a chemical change take place? How do you know?

11 In reference books, read about the following topics: atoms, elements, chemistry, chemists such as Joseph Priestley, Antoine Lavoisier, John Dalton.

When fire cooks our food and keeps us warm, it is one of our best friends. When it destroys our homes and forests, it is one of our worst enemies. Yet whether it is a friend or an enemy, it is caused by the same things. What do you think is needed to start a fire and keep it burning? How does knowing what fire is and how it can be started help us control fire?

UNIT 6

How do we use and control fire?

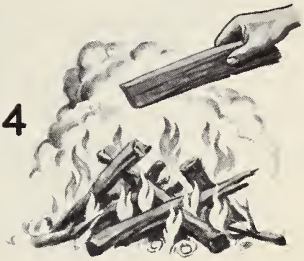
LOOKING AHEAD TO UNIT 6

For thousands of years, people have used fire to make their lives more comfortable. Fire did more for people than almost anything else. With its light they could see at night and scare away wild beasts. With its heat they could keep warm, cook food, make weapons and tools, and change clay into brick and pottery. Fire also helped clear forests for fields and villages. But too often fire terrified people. It roared through woods and fields, destroying valuable hunting grounds as well as the homes and lives of the hunters. As people learned new uses for fire, the disasters caused by it became even greater. However, fire was so useful that people kept on using it.

In early times, making a fire was a hard thing to do because there were no matches. For this reason, an interesting custom was common in some countries. Each village kept a public fire that was never allowed to go out. Here people came to get fire to light their fireplaces and ovens. This public fire was so important that often village meetings were held around it.

You can see that fire has been important in people's lives for a long time. We would not have many of the things that we have today if we did not understand fire and how to use it. But until about 150 years ago, no one really understood what happened when things burned. Fire seemed to change burning materials into almost nothing. Only after doing many experiments, did chemists finally discover what fire is. But what is there to learn about fire? Why should you understand burning before you try to start or put out fires? Here is a story that will help you answer these questions.

It was the first overnight hike for many of the Boy Scouts in the Beaver Patrol of Troop 4. After hiking all afternoon, the boys were tired and hungry. So at dusk the patrol leader chose a place to camp. He picked a spot for the campfire more than 10 feet away from the nearest trees and bushes. Several of the boys cleared a circle 6 feet across by scraping away the leaves, dry grass, and twigs. Other boys went out after wood. They brought back the dead branches of trees. Some branches were as thin as a pencil, while others were thicker.



The patrol leader picked out a dry stick. With his knife he made a little pile of shavings in the center of the cleared space. He piled small sticks and twigs in the shape of a pyramid on top of the shavings. Then crouching in front of the wood with his back to the wind, he lit a match by rubbing it on the side of the matchbox. There was a burst of light as the match caught fire. With the burning match, he set the shavings on fire. After they had burned a moment, he slowly added larger sticks of wood, piling them loosely over the fire. Soon the fire gave enough light for the boys to put up their tents and enough heat to cook their food.

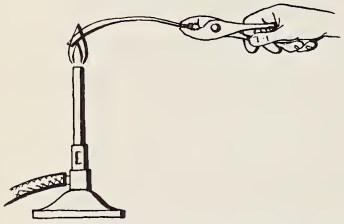
That night the Scouts took turns watching the fire and keeping it burning while the rest of the Beaver Patrol slept. The next morning when the patrol was ready to move on, the boys sprinkled water on the fire until every spark was out. Only wet ashes were left. The boys also soaked the ground around the fire. Finally, they covered the ashes with dirt and sand.

Can you explain why the boys in this story made and put out their fire as they did? Why do you think the patrol leader chose a spot away from trees and bushes? How did the wood shavings help start the fire? What made the match light when it was rubbed on the box? Why was the wood piled loosely around the fire? What caused the heat and light given off by the fire? How did the water put out the fire? You will find the answers to these questions as you study this unit.

1 What is fire?

WHAT DO WE MEAN BY BURNING? In Unit 5 you learned that whenever you light a fire, you bring about a chemical change. You also learned that materials need oxygen in order to burn. And you already know that fire gives off heat and light. In every fire, a material combines with oxygen and gives off heat and light. When a match burns, the materials on the match combine with oxygen and give off heat and light. However, materials sometimes combine with oxygen and give off little heat and no light. This happens when iron rusts. Yet the same kind of chemical change takes place as when something burns. You can see this for yourself by doing two experiments.

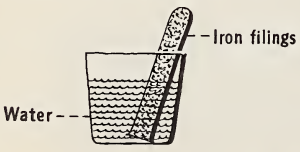
Experiment 1 What happens when magnesium burns?



1 Heat the lower end of the magnesium ribbon red-hot. DO NOT LOOK DIRECTLY AT IT. What happens when magnesium burns?

2 What do you think the new material is made of? Why? Did the chemical change take place quickly or slowly?

Experiment 2 What happens when iron rusts?



1 Wet the inside of the test tube. Put a teaspoonful of iron filings (or a small wad of steel wool) into it. Shake the test tube until the filings stick all over the inside. Then quickly set the test tube upside down in a glass of water.

2 How far does the water rise in the test tube? Why does it not rise farther? When oxygen is taken out of the air in the test tube, what will happen to the water?

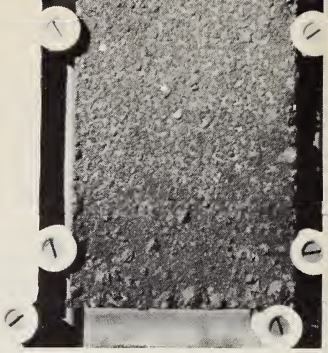
3 Let the test tube stand for one or two days until the iron rusts. Then look at it carefully. What has happened to the water in the test tube? How do you explain what you see?

4 With your thumb over the mouth, lift the test tube out of the glass and turn it right side up. Quickly take your thumb off the test tube and put a burning splinter down into the air above the water. What happens? Why?

5 What is iron rust made of? How is the rusting of iron like the burning of magnesium? How are they different?

When oxygen from the air combines with magnesium, a new material is made. So you know that a chemical change has taken place. You know that this new material is a compound because it contains elements that have combined. You remember from Unit 5 that if mercury is heated in air, it combines with oxygen to form the compound mercuric oxide. The white powder that was made in Experiment 1 is the compound magnesium oxide. And the red iron rust that was made in Experiment 2 is the compound iron oxide. All compounds that contain oxygen and one other element are called oxides. You can now write a sentence to explain what happens in each of these experiments: (1) Magnesium, a silvery metal, and oxygen, a colorless gas, combine to form magnesium oxide, a white powder. (2) Iron, a silvery metal, and oxygen, a colorless gas, combine to form iron oxide, or rust.

The burning of magnesium and the rusting of iron are both examples of the same kind of chemical change. Both elements combine with oxygen, or *oxidize*. This chemical change is called *oxidation*. When magnesium burned, heat and light were given off. However, when iron rusted, you did not notice any heat or light. Scientists know that when any material oxidizes in this way, heat is always produced. But if a material combines slowly with oxygen, you cannot feel the heat. This is true of rusting iron. Iron and oxygen combine so slowly that you cannot feel any change in temperature. And, of course, the iron never gets hot enough to glow and give off light. However, magnesium combines so



When oxidation takes place very rapidly, an explosion often occurs. That is how the fire in this factory was started. The other picture shows very slow oxidation. It took two years for this amount of rust to form on the piece of metal that was left out in the damp air.

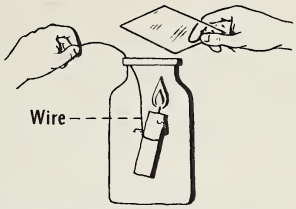
rapidly with oxygen that much heat and light are produced. When oxidation takes place so rapidly that heat and light are produced, we call the chemical change burning, or *combustion*. Combustion is rapid oxidation, while rusting is slow oxidation. Yet they are the same kind of chemical change. In both combustion and rusting, oxygen combines with another element and forms an oxide.

SELF-TESTING EXERCISES

1 **a** In what way are the burning of magnesium and the rusting of iron alike?
  b In what two ways are they different?
2 Why are much heat and light produced when magnesium burns but not when iron rusts?
3 Why are burning and rusting both called oxidation?
4 **a** How is combustion different from rusting?
  b How are they alike?

WHAT HAPPENS WHEN MATERIALS BURN? You have learned that in burning, or combustion, the burning material changes into one or more different materials. For example, some candles are made of paraffin. Paraffin is a compound made of two elements, carbon and hydrogen. When such a candle burns, the paraffin must change into one or more different materials. Do Experiment 3 to find out what these materials are.

Experiment 3 What happens when a candle burns?



1 Light the very tip of the wick and notice what happens as the flame grows larger. What happens to the paraffin around the wick? Is the center of the flame light or dark?

2 Hold a match stick across it just above the wick. When the stick starts to burn, quickly take it out of the flame and stop the burning. Does burning take place inside the flame or around the edges? How do you know?

3 Now blow out the candle and quickly bring a lighted match just above the wick. What happens? Is paraffin a solid, a liquid, or a gas when it burns? How do you know?

4 Hold a white dish in the yellow part of the flame for several minutes. What is the black material on the dish? Where did it come from?

5 Lower the lighted candle into the glass jar and quickly cover the jar with a piece of glass. After a few seconds take the candle out and quickly put the cover back on the jar. Pour a little limewater into the jar and shake it up with the air inside. What do you notice? Limewater is a test for carbon dioxide, which makes it turn milky. Does the burning candle give off carbon dioxide?

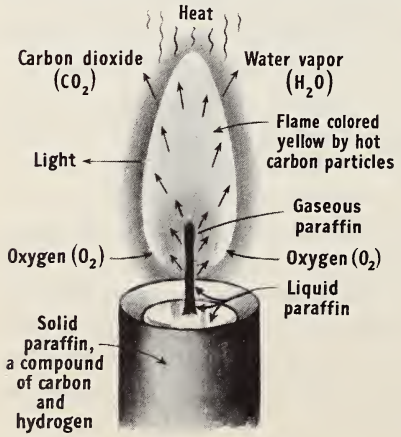
6 Hold a cool glass over the lighted candle but do not let it touch the flame. What appears on the inside of the glass? What do you think this material is? Where did it come from?

You can now understand several facts about burning. You found that other materials were formed from the burning candle. So you know that a chemical change took place. How does this chemical change come about? First, heat from the burning match melts the paraffin in the wick and changes some of it to a gas. The hot gas combines with oxygen in the air and burns. Then the heat from the burning gas melts the paraffin at the top of the candle. This paraffin travels up the wick just as ink soaks through blotting paper. As this melted paraffin reaches the flame, the heat also changes it to a gas. The paraffin gas decomposes into its elements, carbon and hydrogen. The carbon particles in the flame become so hot that they glow and give off a yellow light. When the carbon particles reach the outside of the flame, they combine with oxygen and form carbon dioxide. The hydrogen from the paraffin also combines with oxygen to form hydrogen oxide, or water, in the form of a vapor. Both carbon dioxide and water vapor are colorless gases that mix with the air.

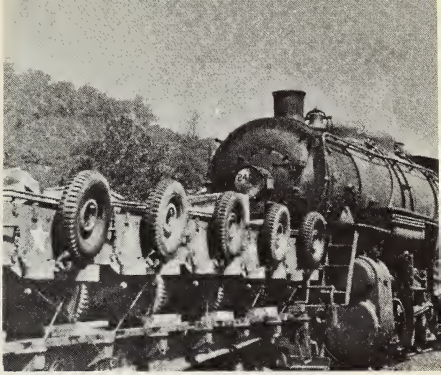
Now you can write three sentences that will show what happens when a paraffin candle burns: (1) Paraffin, a solid white compound, decomposes into its elements, carbon and hydrogen. (2) Carbon, a black solid, and oxygen, a colorless gas, combine and form carbon dioxide, a colorless gas. (3) Hydrogen, a colorless gas, and oxygen, a colorless gas, combine and form water vapor, a colorless gas.

If you understand what happens when a candle burns, you can understand what happens when anything burns. Fuels such as coal, oil, wood, and gas contain compounds of carbon and hydrogen. Some fuels, such as coal and wood, also contain minerals. Because these minerals do not combine with oxygen, they are left as ashes. Sometimes when fuels burn, smoke is given off. Black smoke shows that some of the carbon did not burn. Often there is not enough oxygen to make all of the carbon burn, or the carbon may not be heated enough to combine with oxygen. In either case, the particles of carbon go into the air without burning. Sometimes whitish or bluish smoke is given off by fires. This smoke is not carbon. It is powdered ashes and other materials that do not change to colorless gases as the fuel burns.

When fuels burn without enough oxygen, some carbon monoxide (CO) is usually formed, as well as carbon dioxide (CO_2). You have already learned that carbon monoxide is a very poisonous



Why does the candle get smaller and smaller as it burns?



A way has been found to control smoke. Jets of air are forced over the fire to supply more oxygen. Then the materials that would form the smoke are burned before they can go up the chimney.

gas. Some of it is formed when gasoline burns in an automobile engine. The poisonous gas then comes out of the exhaust pipe. That is why you must never stay in a closed garage while an automobile engine is running.

SELF-TESTING EXERCISES

1 When wood and coal burn, carbon dioxide and water are formed. What does this tell you about the elements in these fuels?
2 Why do gas and oil disappear completely when they burn?
3 What does black smoke coming from a fire show?
4 Why should you not stay in a closed garage when an automobile engine is running?

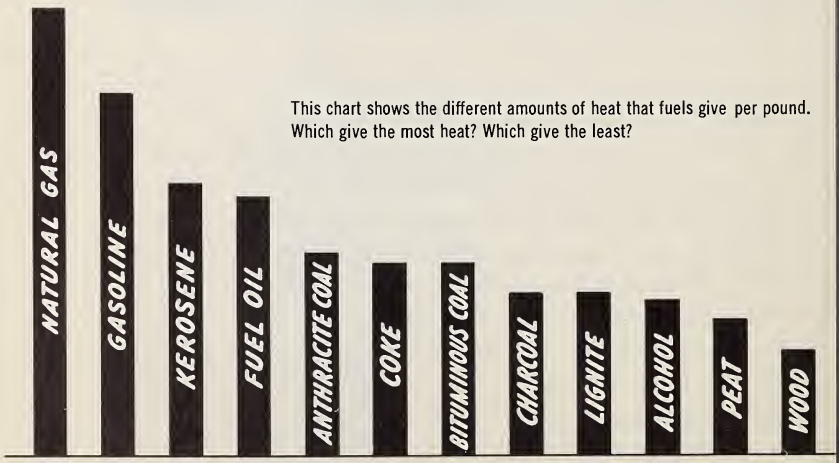
PROBLEMS TO SOLVE

1 Explain how a flame is produced when wood burns.
2 The white powder that is left after magnesium burns is heavier than the magnesium. How can you explain this?
3 How do you know that iron takes oxygen from the air when it rusts?
4 When set over a lighted gas burner, the outside of a teakettle full of cold water often becomes coated on the bottom with a film of water. Where does the water come from?
5 Do you think that the wire inside an electric-light bulb burns when the current is turned on? Give reasons for your answer.
6 Are you getting your money's worth from coal or oil burning in a furnace if black smoke pours from the chimney? Explain.

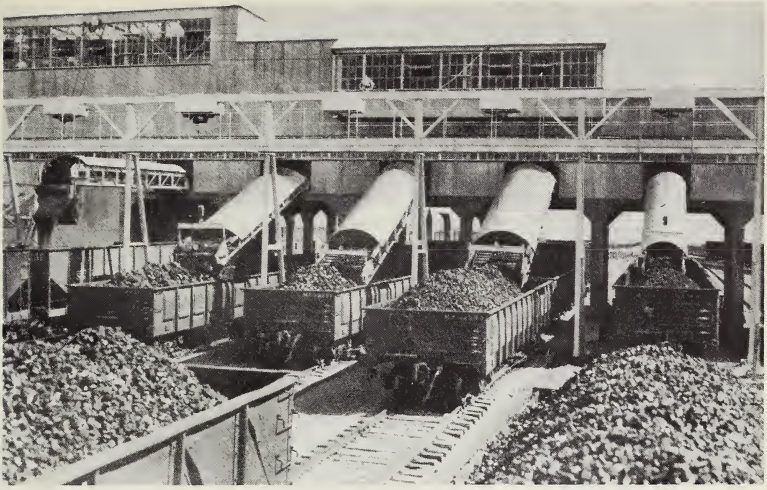
2 How do we make a fire?

WHAT MATERIALS WILL BURN? To make a fire, we must have something that will burn. Any material that will burn is called a combustible material. Paper, cloth, wood, and coal are all combustible materials. Of course many materials will not burn. Water and glass will not combine with oxygen at all. Other materials will combine with oxygen but not fast enough to give off much heat and light. Any material that will not burn is called an incombustible material.

Although burning also gives off light, what we usually want from a fire is heat. So our most important combustible materials are those that are used for fuels. To be a good fuel, a combustible material must burn rather easily and give off large amounts of heat. We must also be able to get enough of the fuel without paying too much for it. People who use fuel carefully also consider how easy the fuel is to handle and burn and how much smoke, ashes, and dust it makes. There are three main types of fuels: (1) solids such as wood, coal, coke, and charcoal; (2) liquids such as gasoline, kerosene, and fuel oil; and (3) gases such as natural gas and manufactured gas.



This chart shows the different amounts of heat that fuels give per pound. Which give the most heat? Which give the least?



After coal is mined, it is washed and sorted according to size. Then it is loaded into freight cars and shipped to all parts of the country.

At one time, wood was our most important fuel because it was the easiest to get. But so many of our forests have been cut or burned that wood is no longer so easy to get. Moreover, other fuels are better than wood for several reasons. Wood does not give as much heat per pound as other fuels. One pound of coal gives about as much heat as two pounds of wood. To get enough heat from a wood fire, we must use a good deal of wood. And because wood burns faster than coal, we must often add more wood to the fire. In cities, wood is seldom used as a fuel except for starting fires. However, it is still a common fuel where better fuels are hard to get or are too costly.

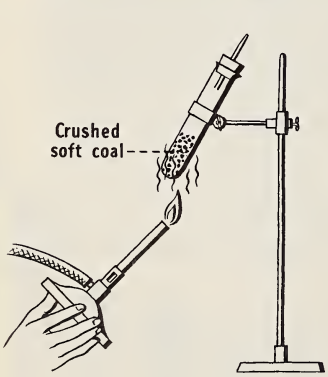
Coal is the most common fuel used today. In most parts of our country, it is the cheapest and best fuel for the amount of heat it produces. The two most important kinds of coal are soft, or *bituminous,* coal and hard, or *anthracite,* coal.

Bituminous coal is the most widely used kind of coal because it gives the most heat per dollar. Different grades of bituminous coal contain from forty to eighty per cent of pure carbon. The rest of the coal is mostly made up of compounds that form

gases when the coal is heated. When the coal is burned, these gases are often not completely burned. Besides causing a loss of heat, the unburned gases make a great deal of smoke. This is the main disadvantage of bituminous coal. Anthracite coal contains more than ninety per cent pure carbon. It burns with a small flame and gives very little smoke. Although it does not burn as easily as bituminous coal, anthracite coal burns more slowly and needs less attention.

Coke is used mainly in getting iron from its ores, but it is also important as a fuel for home use. It is made by heating bituminous coal in large ovens until most of the gases have been driven off. When coke burns, it gives a large amount of heat without smoke. Because coke is rather hard to start burning, it is often mixed with bituminous coal in home furnaces. The coal burns more easily than the coke and helps keep it burning. If you would like to make some coke, you can do Experiment 4.

Experiment 4 How are coke and gas made from soft coal?



1 What do you need to do this experiment?

2 Heat the coal strongly, moving the flame around so that all of the coal is heated but the glass does not melt. What happens?

3 Light the gas that is given off. When no more gas is given off, stop heating the test tube.

4 Let the test tube cool. Then break the test tube and examine the coke.

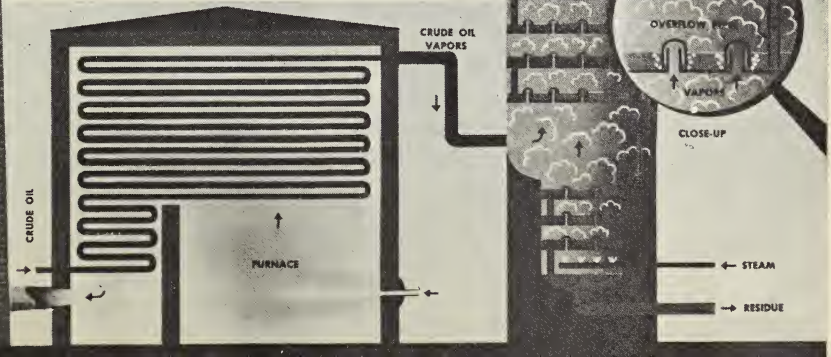
5 What kind of chemical change took place in the experiment? How do you know?

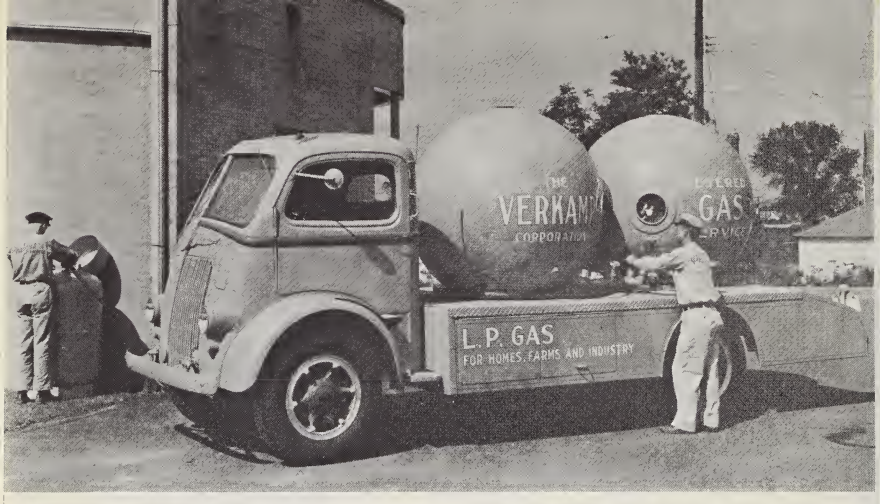
Charcoal is made from wood in the same way that coke is made from coal. If you did Experiment 6 in Unit 5, you made some charcoal. Like coke, it burns without smoke.

Fractional distillation takes place in a tall tower. Find the different products that are obtained from the crude oil.

In recent years, liquid fuels have become more important for several reasons: (1) They are easily handled and transported. (2) They are easily stored. (3) They are easy to light and regulate. (4) When properly burned, they produce no smoke or ashes. (5) They give more heat per pound than solid fuels.

The most widely used liquid fuels are gasoline, kerosene, and fuel oil. These fuels are all obtained from crude oil, or petroleum, that comes out of oil wells. Petroleum itself was used as a fuel before chemists discovered that it could be separated into gasoline, kerosene, fuel oils, lubricating oil, and many other products that we use today. These materials are separated from petroleum by a process called fractional distillation. In this process, the crude oil is vaporized in large stills. As each material is cooled below its boiling point, it is condensed back to a liquid and then led into a separate pipe. After all these materials have been separated from the petroleum, asphalt or petroleum coke may be left in the still.





Gas from the large tanks on the truck is put into the smaller tank outside the building. From there it is piped into stoves or heaters.

Gasoline produces almost twenty-five per cent more heat per pound than high-grade anthracite. It is used mainly in the engines of automobiles and airplanes because it vaporizes easily. Some gasoline is also used in stoves and lamps. Kerosene is used in jet airplanes and also in stoves and lamps where other fuels are not available. Fuel oil, which is much like kerosene, is widely used in homes, locomotives, and ships.

Gases are the easiest and cleanest fuels to handle and burn. However, in most communities gas is more expensive than coal or oil. The first gas used for fuel was manufactured. If you did Experiment 4, you made a kind of manufactured gas called coal gas. It is the most widely used artificial gas for heating purposes. Though much manufactured gas is still being used, natural gas is being used more and more as a fuel. It gives more heat per cubic foot than manufactured gas. Natural gas is sometimes found dissolved in petroleum or above petroleum in oil wells. It is often found where there is no oil at all. Where gas is not available from pipes, both natural and manufactured gas may be bottled, or compressed in steel containers. The gas is then sold in these containers, which can be connected to stoves to give the same kind of heat as piped gas.

SELF-TESTING EXERCISES

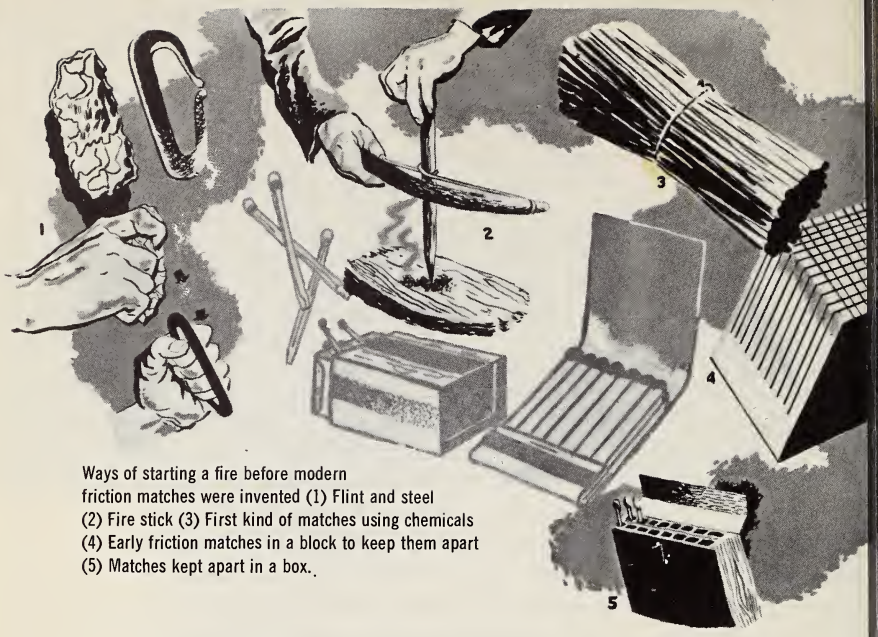
1 **a** What are the main requirements for a good fuel?
b What other things should a careful buyer of fuel consider?
2 Name the three main types of fuels and give at least two examples of each type.
3 Why does bituminous coal give off more smoke than anthracite coal?
4 How are coke and gas made from bituminous coal?
5 How do we get gasoline, kerosene, and fuel oil from petroleum?
6 Where is natural gas found?

HOW DO WE MAKE MATERIALS HOT ENOUGH TO BURN? You cannot make a fire unless you first have a combustible material, but all combustible materials do not catch fire easily. You cannot set fire to a piece of coal with a lighted match. Yet when you hold a lighted match to a piece of paper, the paper bursts into flame almost at once. You need only a little heat to make paper hot enough to burn. Coal must be heated much hotter before it will burn.

The temperature at which a combustible material will catch fire and start to burn is called its kindling temperature. Materials that catch fire easily, such as paper and wood splinters, have low kindling temperatures. Materials that do not catch fire easily, such as coal, have high kindling temperatures. Some kinds of coal must be heated very hot before they reach the kindling temperature and start burning.

Materials that can be heated to their kindling temperatures quickly are used to heat materials that do not catch fire so quickly. In making a fire, you put the materials that catch fire easiest, such as paper and wood shavings, on the bottom. Above them you put larger sticks of wood, which must be heated enough to bring them to their kindling temperature. Coal is put on a fire last because it has a higher kindling temperature than paper or wood. In this way, the heat from the burning paper passes up through the wood and starts it burning. Then the heat from the burning wood makes the coal hot enough to burn.

Before matches were invented, the biggest problem in starting a fire was to get things hot enough to burn. Early pioneers in America used tinder, flint, and steel to start their fires. Tinder is



Ways of starting a fire before modern friction matches were invented (1) Flint and steel (2) Fire stick (3) First kind of matches using chemicals (4) Early friction matches in a block to keep them apart (5) Matches kept apart in a box.

anything that catches fire easily. It is usually made from cotton or linen cloth or from the dried bark of trees. To start a fire, some tinder was put on the ground. Then the flint rock was struck against the steel to make sparks that would set the tinder on fire. If a pioneer could not make a fire with his flint and steel, he might have to carry an iron kettle for miles to get fire from a neighbor.

When chemists learned that they could get heat by mixing certain chemicals, they tried to find a quick, easy, and safe way of starting fires. The first friction matches were made about 125 years ago. Modern matches contain (1) a chemical with a low kindling temperature, (2) another chemical that gives off oxygen when heated, (3) ground glass to increase friction, and (4) glue to hold the chemicals on the stick. When a match is rubbed on a rough surface, friction makes the match head hot enough to burn. Safety matches must be struck on a specially prepared surface. They will not light when rubbed on just any rough surface.

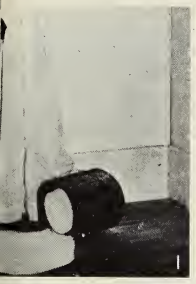
Electric current is also used to make things hot enough to burn. The wires in toasters and irons can be heated red-hot by electric current. If this heat is not properly controlled, it can easily set

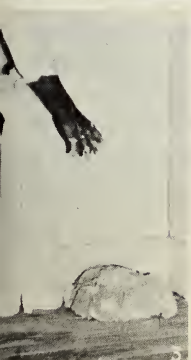
things on fire. Electric current is also used in automobile and airplane engines to set the gasoline vapor on fire.

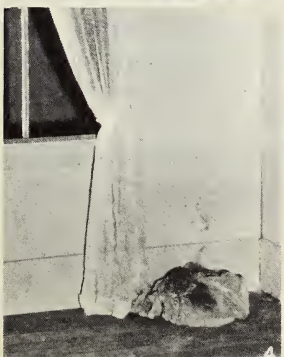
Sometimes combustible materials make themselves hot enough to burn. When this happens, we call it *spontaneous combustion,* or self-burning. It often takes place in rags that have been used to wipe up linseed oil or paint made from linseed oil. This kind of oil combines slowly with oxygen and gives off heat. When the oil is spread out on the side of a house, the heat is carried away in the air. But when the oil is inside a pile of rags, the heat cannot escape fast enough. The rags get warmer and warmer until they reach their kindling temperature and burst into flames. Piles of coal or damp hay sometimes start fires by spontaneous combustion.

SELF-TESTING EXERCISES

1 What does kindling temperature mean?
2 Why does paper catch fire more quickly than coal?
3 How should combustible materials be arranged in making a fire?
4 Explain why each material in a friction match is used.
5 Name three different ways to make things hot enough to burn.
6 What is spontaneous combustion? How does it take place?







These pictures show how a fire can light itself. Explain what happened after the paint was wiped up with a cotton rag.

How do fires get oxygen? You know that to start a fire, a combustible material must be heated to its kindling temperature. In Unit 5 you learned that a fire needs oxygen in order to burn. Once a fire has started, it must have a steady supply of oxygen to keep burning. If a burning candle is put under a jar or inside a stoppered bottle, it goes out as soon as the supply of oxygen has been used up. But a candle left burning out in a room never runs out of oxygen. A bonfire in the yard does not run out of oxygen. Do Experiment 5 to find out how a fire provides its own supply of oxygen from the fresh air around it.

Experiment **5** How does a fire get its supply of oxygen?

1 What do you need to do this experiment?

2 How can you use a piece of smoking paper (or wood or punk) to follow the currents of air around a fire? Try it and see what happens.

3 In what direction is the air moving? How do you know?

4 What becomes of the used air?

5 How does a fire get its supply of oxygen?

6 Make a drawing to show the currents of air around a burning candle.

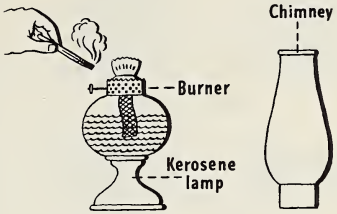
You remember from Unit 4 that when materials are heated, they expand. Scientists know that they also get lighter. So when the air next to the fire becomes hot, it expands and gets lighter. Then the heavier, cool air settles down around the candle, pushing the lighter, warm air upward. Cool, fresh air is pushed into the fire as warm, used air is pushed away. As the used air rises, it takes with it the gases from the fire. A strong, fast current of air provides more oxygen for the fire. So the fire burns more brightly. You can find out how a chimney helps a fire burn better by doing Experiment 6.

Experiment **6** How does a chimney help a fire burn better?

1 What do you need to do this experiment?

2 How can you find out where the current of air goes into the burner? Try it and see.

3 Now turn up the wick until the burner begins to smoke. Set the chimney on the lamp. What happens? Why?



4 Again test the current of air that goes into the burner. What do you notice? Answer the question of the experiment.

5 Plan an experiment using a candle instead of the burner. Try it and see what happens. Do you get the same results?

The chimney of a kerosene lamp separates the warm air above the flame from the cool air outside the chimney. So the current of air moves faster, and the flame gets a better supply of oxygen. When there is plenty of oxygen, kerosene burns faster and makes a brighter flame. Stoves and furnaces also have chimneys to give fires a better supply of oxygen. If you have ever tended a fire in a stove or furnace, you know how the air rushes through when the doors are open. This movement of air up through the fire is called a draft. Besides helping make a good draft, chimneys carry smoke and sparks from fires high up into the air. In this way, they help protect buildings from fires.

SELF-TESTING EXERCISES

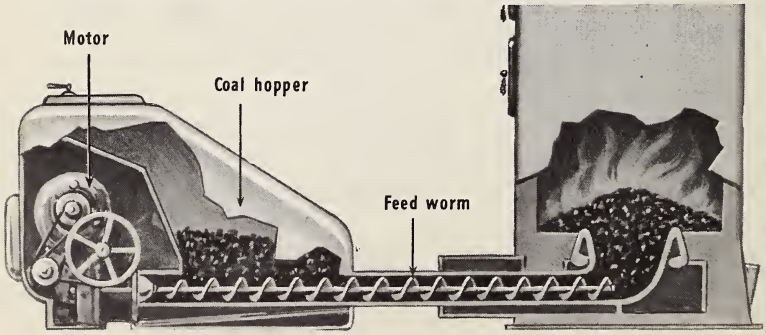
1 State three things that are needed to start a fire and keep it burning.
2 How does a fire get its supply of oxygen?
3 State two reasons why we use chimneys in our buildings.

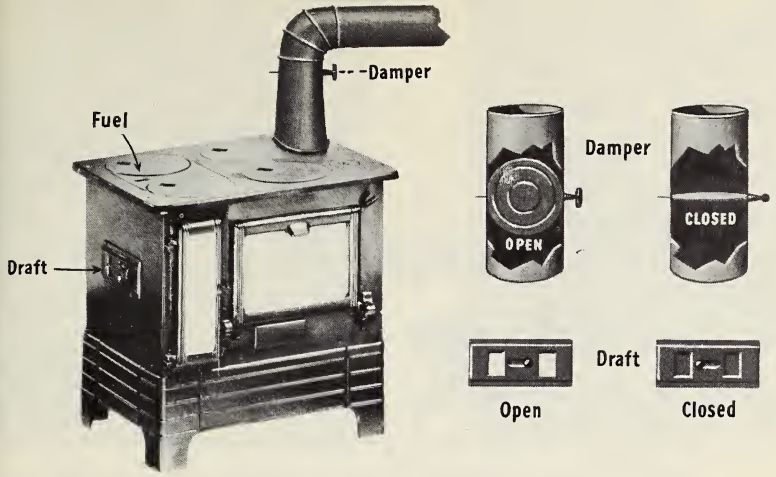
HOW DO WE REGULATE FIRES? People used open fires for thousands of years. Then they discovered they could get more heat by inclosing the fire in an incombustible box. A fire in a

stove or furnace gives more heat to a room with less fuel than an open fire in a fireplace. A stove is an incombustible firebox made of iron or steel. It usually provides heat for only one or two rooms. A furnace is a big stove that has a jacket around it filled with air or water. It can supply heat to an entire building. Let us see how the fires in stoves and furnaces are regulated.

You know that any fire must have three things in order to burn: (1) a combustible material, (2) enough heat to raise the material to its kindling temperature, and (3) a supply of oxygen to keep the material burning. If any one of these is lacking, a fire will not start. Or if you take away one of these from a fire that is already burning, the fire will go out. If we can regulate the supply of fuel or the supply of oxygen or both, a fire will burn as rapidly or as slowly as we wish. How the fuel and oxygen are regulated in a stove or furnace depends on the type of fuel that is burned.

A wood or coal fire can be controlled by regulating both fuel and oxygen. If the supply of fuel is shut off, the fire will stop burning. Too much fuel can also put out the fire by shutting off the supply of oxygen. The fuel can be easily regulated in a coal furnace with a machine called a stoker. The stoker feeds coal into the firebox whenever fuel is needed to keep the building at a certain temperature. One advantage of a stoker is that it feeds the fresh coal into the bottom or side of the fire instead of the top. In this way, the gases are heated as they go up through the hot coals. Then they combine quickly and easily with oxygen and burn more completely. The picture below shows how a stoker works.



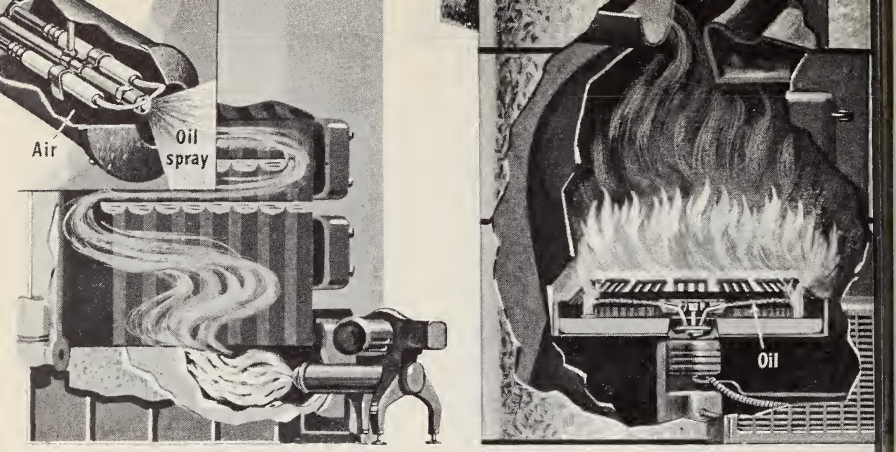


How should the draft and damper be regulated when you want to start a fire? When you want to make it burn more slowly?

The supply of oxygen in a wood or coal burner is regulated with a draft door and a damper. The draft door is below the grates that hold the fuel. It can be opened to let in more air or closed to let in less air. The damper is in the pipe leading to the chimney. It is used to open or close the pipe. To start a fire, the draft door and the damper should both be opened. Then the air can come in at the bottom, pass up through the fire, and go out of the pipe to the chimney. In this way, the fire gets enough oxygen to give it a good start.

In burning coal or wood, both the fuel and oxygen are regulated. However, in burning oil or gas, the fire is controlled mainly by regulating the fuel. Once the oxygen supply is adjusted, only the fuel is regulated. To burn oil without smoke, the oil must first be changed into a very fine mist or else completely vaporized. One way of doing this is to pump the oil through a tiny nozzle under high pressure. At the same time, an electric fan blows a current of air past the nozzle. An electric spark sets the mixture of fuel and oxygen on fire. The fire will then burn until the electric motor that runs the pump and fan is stopped.

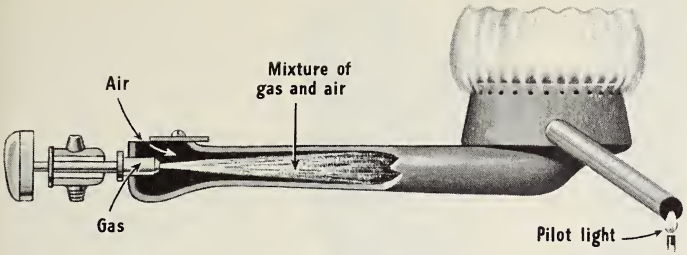
Another kind of oil burner has a disk in the center of the furnace. An electric motor whirls the disk at high speed. The oil



The burner on the left is the pressure, or gun, type of oil burner. On the right is the kind in which a whirling disk throws the oil outward toward the side of the firebox. As the oil flies outward, it passes over a hot metal ring. The heat from this ring sets the oil on fire.

comes up into the disk and is thrown outward against the sides of the firebox, where it burns. The whirling disk also acts as a fan to bring a current of air into the firebox. In a third kind of oil burner, the oil comes into the bottom of the burner through a pipe. The fuel changes to a gas when it is heated. Openings around the bottom of the burner let fresh air into the burner. The fuel mixes with the right amount of oxygen to make the fire burn with a clean, blue flame. By turning a knob, you can regulate the amount of oil that enters the burner. Some kerosene burners have wicks like a kerosene lamp. These burners are regulated by turning the wick up or down.

A gas fire is controlled in much the same way as the fire in an oil burner. The amount of gas can be regulated by turning a valve. A gas burner gives the cleanest fire, and it is also the easiest to regulate. Gas and oxygen are brought into the burner through pipes or other openings. These openings are arranged so that the gas and oxygen mix before being set on fire. A gas burner must be carefully adjusted to mix the right amount of oxygen with the gas. If this is not done, the gas will burn with a yellow flame or it may go out. After the oxygen supply has been adjusted, only the fuel is regulated.



Study the picture on this page carefully. Notice the hole where the oxygen goes in to mix with the gas. This hole is partly covered with an adjustable metal plate. By loosening a screw, the opening can be made large or small. When the opening is closed, the gas flame becomes yellow. When the hole is opened the right amount, the flame becomes blue and will neither smoke nor burn noisily. You can learn how a gas burner is regulated by doing Experiment 7.

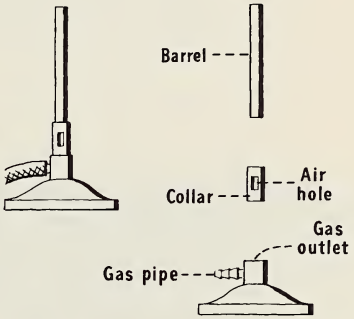
Experiment 7 How is a gas burner regulated?

1 Take the gas burner apart and find each part shown in the picture.

2 Turn on the gas just a little and light the stream that comes from the outlet. What color is the flame?

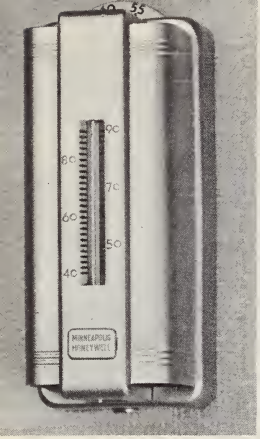
3 Turn off the gas and put the burner together again. Open the air holes and light the gas at the top of the barrel. What color is the flame? Close the air holes. What color is the flame now? Why?

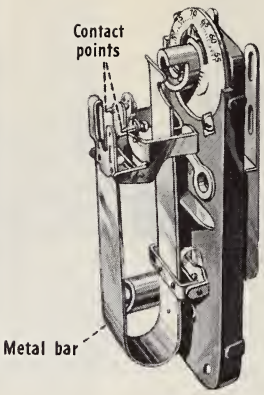
4 Leave the air holes closed. Put a piece of iron screen or wire gauze in the bottom of the flame and move it slowly upward. Watch the color of the wire. Where is the hottest part of the flame?



5 Open the air holes and find the hottest part of the flame. Where is it? In which flame does the wire get hotter? Why?

6 Leave the air holes open. Hold a white dish over the flame. Then close the air holes. What happens to the dish? Why? Which flame is cleaner?





The metal bar of the thermostat is made of brass on the inside and another metal on the outside. When the temperature goes down, the bar bends inward and touches the contact points. What principles of science that you learned in Unit 4 explain why this happens?

The fire in a coal, oil, or gas burner can easily be regulated by using a *thermostat.* This device is a kind of thermometer that can be set at a certain temperature. It automatically keeps this temperature by controlling the fuel or oxygen supply in a fire. A thermostat will turn the stoker of a coal furnace off or on. It will also control the electric motor that opens and closes the draft door and the damper. The fuel supply in an oil or gas burner can be controlled by a thermostat, too.

SELF-TESTING EXERCISES

1 How are a furnace and a stove alike? How are they different?
2 **a** State two ways in which a fire can be regulated.
b How is the fire regulated in a coal or wood burner? An oil burner? A gas burner?
3 Which kind of fuel burner is easiest to regulate? Why?
4 What are the advantages of using a stoker with a coal furnace?
5 Why are thermostats often used with furnaces and stoves?
6 **a** If the flame of a gas burner is yellow, what does this show?
b How can it be changed to a blue flame?
7 To keep an oil burner from smoking, what must be done to the fuel?

PROBLEMS TO SOLVE

1 Not all combustible materials are used as fuels. Why?
2 **a** What fuel is used to heat your home?
b What are the reasons for using this fuel?

3 If all fuels gave the same amount of heat for the same cost, which fuel would you prefer to use? Give reasons for your answer.

4 **a** When more fuel is added to a coal fire, black smoke often comes out of the chimney. Why?

b How can this smoke be prevented?

5 Read again the story about the Boy Scouts on pages 180-181 and look at the picture on page 181. Then explain why the patrol leader built the fire as he did.

6 If a glowing splinter is put into pure oxygen, it will burst into flame. Why do you think that this happens?

7 Explain why you can often feel a wind near a large fire.

8 Why does a kerosene lamp smoke if the wick is turned up too high?

9 How do the bottoms of pots and pans used on a gas stove show whether enough air is being mixed with the gas?

10 Why must ashes be removed from coal or wood furnaces and stoves?

11 Fanning a smoldering fire will make it burst into flame. Why?

12 **a** In starting a coal or wood fire in a stove or furnace, you should open the draft door and damper as far as you can. Explain.

b After the fire is well started, how should the draft door and damper be arranged? Why?

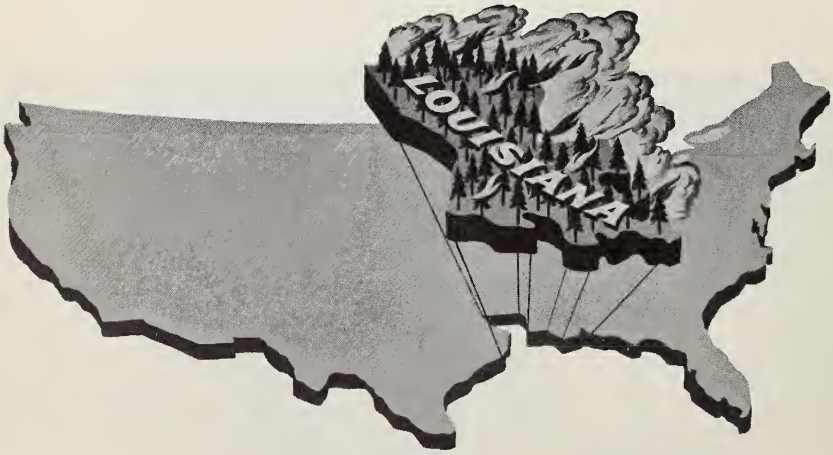
c How would you arrange the draft door and damper so that the fire will burn all night without going out?

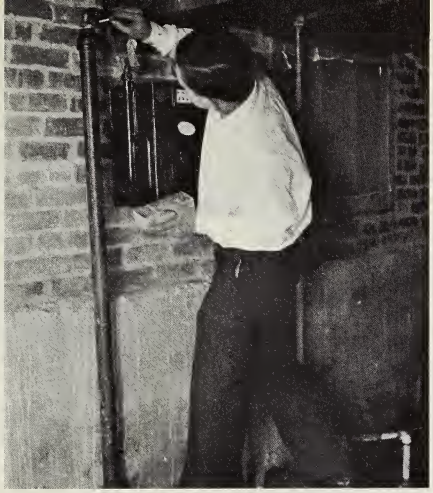
Why are these boys blowing on the fire?

3 How can we prevent and extinguish fires?

HOW ARE FIRES PREVENTED? You have learned how to start a fire and keep it burning. Sometimes we want to keep a fire from getting started. Accidental fires cost many lives and millions of dollars each year. For the past twenty years in our country, there has been more than one destructive fire every minute. About seventy-five fires start every hour, more than 1800 every day. In the past ten years, over 100,000 people have been killed by fires and over twice that many injured. In one recent year, 11,000 people lost their lives in fires. The cost of these same fires in money was over $725,000,000.

There are about 2000 forest fires every year. The forest land destroyed in a year by these fires is equal to the whole State of Louisiana. Think of it! Forests and wild life, homes and schools and churches, factories and stores are going up in smoke. And most of these fires are caused by carelessness or ignorance. Many things can and are being done to stop this terrible loss from fire. Building materials that will not burn, greater care, and





What dangerous things are being done in these pictures? Why are they dangerous? What should be done instead?

better ways of fighting fires are all helping to reduce the loss. But fires are still costing more than thirty lives and $2,000,000 a day. The pictures above and on page 207 show some of the most common causes of accidental fires.

Every accidental fire happens because of one thing: A combustible material gets too hot. Wherever there is air, there is oxygen. And of course air is almost everywhere. So a fire may start whenever combustible materials are next to something hot. The first way of preventing fires is to keep fire or anything hot away from combustible materials. You can do this in many ways. For example, allow at least 24 inches between a stove or furnace and any wall. Never store waste paper or rubbish near a stove or furnace. Since ashes often have live coals in them, they should be put into metal cans or brick or concrete bins. Lighted cigars and cigarettes should be laid on metal, porcelain, or glass. Lighted matches, candles, and lamps should never be held near combustible materials. Never try to find a gasoline or oil leak or even search in closets with a match or candle. Lighted matches should be broken in two after they are put out. Fires should be built only on soil, metal, stone, or brick. Bonfires should not be made close

to wooden fences or buildings. Buildings that are close to each other should be built of fireproof materials.

Many fires are started by carelessness with electricity. Electric wires should be properly connected and large enough so that they will not overheat. They should be insulated so that they do not touch combustible materials. Electric fuses should be of the right type and size. Never use a penny to replace a blown fuse. Fires are sometimes started by an electric spark. If you have ever rubbed your feet on a rug and then touched another person or a doorknob, you probably felt a slight shock. You may have seen a small spark jump from your finger to the person or the doorknob. Friction between your feet and the rug produced a small amount of electricity. Unless there is a highly combustible material near the spark, this electricity will not start a fire. But this spark could set gasoline or other combustible vapors on fire. This is why it is dangerous to clean clothing with gasoline. Rubbing the cloth, or striking the side of the pan with a metal button or buckle, may cause a spark that will set the gasoline vapor on fire. It is always safer to use a cleaning fluid that will not catch on fire.

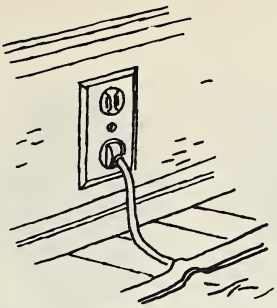
Spontaneous combustion is a common cause of fire. Fires started in this way have caused losses of more than $25,000,000 in one year. The commonest cause of spontaneous combustion is the improper storing of oily rags, mops, and other materials. You learned that such oils slowly oxidize, giving off enough heat to set the materials on fire. To prevent fires caused in this way, oily rags should be stored in closed metal cans. Materials such as sawdust, grain, charcoal, soft coal, raw wool, and hay may also start fires by spontaneous combustion. These materials should not be stored in big piles unless the storage spaces have enough ventilation to carry off the heat.

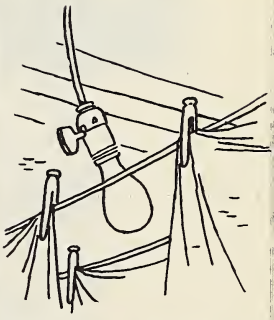
SELF-TESTING EXERCISES

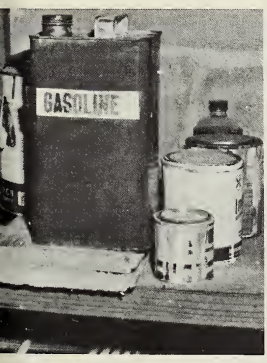
1 Why should fire or hot objects be kept away from combustible materials?

2 What are some ways to prevent fires caused by electricity?

3 Explain how fires that are caused by spontaneous combustion can be prevented.







Which pictures show ways in which fires might be started? Which pictures show ways of preventing fires? Explain your answers.

If you have fire-alarm boxes in or near your school, find out how they work. In some boxes, you open a door and pull down a handle. In other kinds, you must break the glass front of the box to pull the alarm.

How are fires extinguished? In spite of our care, some accidental fires do get started. But if you know what to do when a fire starts, you can often stop it before it does much damage. If you live in a town or city where there are fire-alarm boxes, be sure that you know how to turn in an alarm. Many fires that could have been stopped have got out of control because someone failed to send in an alarm.

If you know what things are needed for burning, you also know how a fire can be put out. Removing combustible materials or cutting off the fuel supply is one way to stop a fire. Forest fires are often fought by clearing a space ahead of the fire or by starting small backfires. The backfires are kept under control while they burn a strip around the main fire. Firemen sometimes have to dynamite buildings to stop a fire from spreading. When they do this, they are removing the combustible materials. An oil or gas fire can be quickly stopped by shutting off the supply of fuel.

A second way that fires can be put out is by cooling the burning materials below their kindling temperatures. Smothering a fire, or shutting off the supply of oxygen, is the third way of stopping

it. The materials commonly used for fighting fires will either cool burning materials below their kindling temperatures or shut off the supply of oxygen, or both. Of course, the most common and valuable material for putting out fires is water. Water and the steam it produces will smother most fires. Water also cools the burning materials below their kindling temperatures. But water should never be poured on gasoline and oil fires. These materials will float on the water and spread without being put out. For small gasoline and oil fires, use sand, dirt, or woolen materials. Never use water to put out electrical fires. Electric current can pass through the water and cause a shock strong enough to kill you.

Using an artificial fog is one method of putting out gasoline and oil fires. In this method, water is pumped under high pressure through a special nozzle. The nozzle breaks the water into many small streams. When the water comes out, it is in the form of a fog. With this fog ahead of them, men can walk into the hottest fire without danger. The fog smothers and cools the fire like a stream of water, but it does not spread the gasoline and oil. An-

All around the top of this oil tank are nozzles that shoot streams of foam down into the tank. The foam very quickly forms a blanket over the blazing oil. How does this put out a fire?

Many airports now have fire trucks that can produce blizzards of carbon-dioxide snow in a very few minutes. What does this do to a fire?

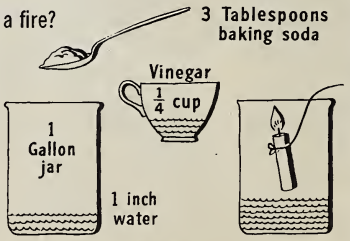
other way to put out gasoline and oil fires is to use foam. The foam is made by mixing water with certain chemicals. A special nozzle throws out snowy bubbles that form a sticky blanket of foam over the fire and shut out the oxygen at once.

Carbon dioxide can be used to put out all kinds of fires. It is especially good for putting out gasoline and oil fires and electrical fires. One kind of fire extinguisher contains liquid carbon dioxide. When you open a valve in the extinguisher, the liquid carbon dioxide shoots out and part of it evaporates. This evaporation cools the rest of the carbon dioxide until it freezes into a fine powder. The result is a blizzard of carbon-dioxide snow at a temperature of 110° below zero F. A fire fighter protected by frozen carbon dioxide can walk right into a fire and actually be cold. The carbon dioxide puts out the fire by cooling the materials below their burning temperature and by cutting off the oxygen supply. Experiment 8 shows you how carbon dioxide puts out a fire.

Experiment 8 How does carbon dioxide put out a fire?

1 Dissolve the baking soda in the water. Then add the vinegar. What happens? The gas is carbon dioxide.

2 Lower the lighted candle into the jar. What happens? Why?



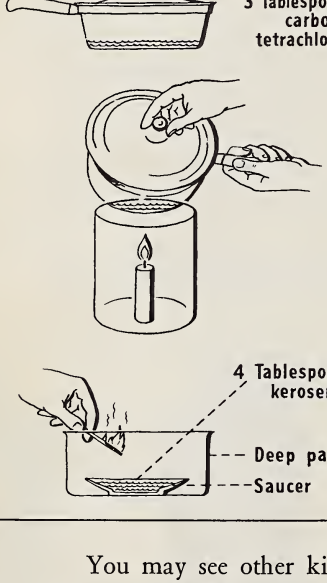
A kind of fire extinguisher you often see in schools and other buildings is a brass tank hung on the wall. This kind of extinguisher is a soda-acid extinguisher. Attached to the top of the tank is a rubber hose with a nozzle. The tank is nearly full of a solution of baking soda in water. A bottle in the top of the tank contains concentrated sulphuric acid. A lead stopper fits loosely in the bottle. When the tank is turned upside down, the stopper falls out. Then the acid mixes with the soda solution, making carbon dioxide. This gas produces a very high pressure and forces the water-soda solution out through the hose. To keep the chemicals fresh, a soda-acid extinguisher should be emptied and refilled every few months.

Another kind of fire extinguisher contains carbon tetrachloride. It is excellent for putting out small gasoline and oil fires and electrical fires. Carbon tetrachloride is a liquid that changes to a vapor quickly when heated. This vapor is much heavier than air. So when the liquid is squirted on a fire, its vapor settles down over

The pictures below show a soda-acid fire extinguisher and how it is held when putting out a fire. The picture on the right shows the inside of the tank. You can see the bottle of acid and the stopper that falls out when the tank is turned upside down.

the burning material and keeps away the oxygen. But this vapor should not be breathed, because it is poisonous. A carbon-tetrachloride extinguisher works like a pump. It is small enough to be carried easily in automobiles, and the liquid does not freeze in cold weather. You can see how carbon tetrachloride puts out a fire if you do Experiment 9.

Experiment 9 How does carbon tetrachloride put out a fire?



1 Pour the carbon tetrachloride into the pan. Cover it tightly for ten minutes while some of the liquid evaporates. DO NOT BREATHE THE VAPOR.

2 Then pour the vapor from the pan into the jar with the lighted candle. What happens? Why?

3 Can you light the candle again without taking it out of the jar? Explain.

4 Light the kerosene in the saucer. Then pour water on it until it runs over the edge of the saucer. What happens?

5 Now pour some carbon tetrachloride on the flaming kerosene. What happens now?

6 Should you use water to put out a kerosene fire? Explain.

You may see other kinds of fire extinguishers. If there are extinguishers near where you study, work, or play, be sure to read the directions on them. You will then know how to use them in case of fire. When you buy fire extinguishers, roofing materials, oil burners, electrical appliances, and other similar products, you should look for labels which tell that these things have been tested and approved by the Underwriters' Laboratories, Inc. This label shows that the things have been made so that they will help prevent fires and other accidents.

Kind of extinguisher	Materials used	Kinds of fires	Kind of extinguisher	Materials used	Kinds of fires
Carbon tetrachloride	Liquid carbon tetrachloride changing to a vapor when it strikes the fire	Gasoline Oil Grease Electrical equipment	Water pump	Water	Wood Paper Rubbish Fabrics
Foam	Foam-making chemicals Bicarbonate of soda to form carbon dioxide	Wood Paper Fabrics Gasoline Oil Grease	Carbon dioxide	Carbon-dioxide gas Some solid carbon-dioxide snow	Gasoline Oil Grease Electrical equipment

What do you think are the advantages of the different kinds of fire extinguishers described in this table?

SELF-TESTING EXERCISES

1 **a** In what two ways does water help put out a fire?
b How can water be used to put out gasoline or oil fires?
2 How does a foam extinguisher put out a gasoline or oil fire?
3 **a** What kinds of fires can be put out with a carbon-dioxide extinguisher?
b How does this kind of extinguisher put out a fire?
4 Explain how a soda-acid extinguisher puts out a fire.
5 Why is a carbon-tetrachloride extinguisher better than a soda-acid extinguisher for a gasoline or oil fire or an electrical fire?

New materials are helping fight fire. In a fireproof suit, a person can walk through flames without harm. Curtains can be made of fireproof material. Water is made wetter by adding a chemical that makes the water soak into materials more quickly. A forest fire was quickly put out by using wetter water.

PROBLEMS TO SOLVE

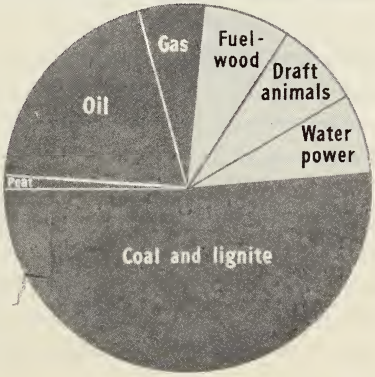
1 How does knowing the requirements for burning help you prevent and put out fires?
2 Make a list of the ways you think a fire might get started in your own home. Then tell how each fire can be prevented.
3 Soot in a chimney sometimes catches fire. How could this set a house on fire?
4 Read again the story on pages 180-181. Explain why each of the things the boys did in extinguishing their fire was important.
5 What are some reasons why fires are often very hard to put out?
6 If a fire starts where there are no extinguishers, what are some things that you might do?
7 If your clothing catches fire, what is the best way to put it out?
8 Why is it a good idea to keep pails of sand in garages?

How can we conserve fuel? 4

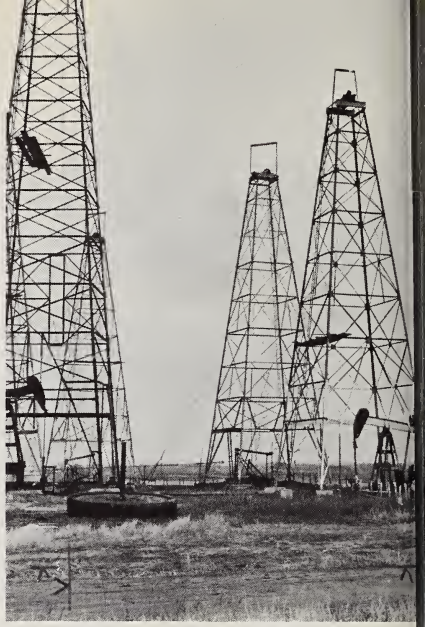
WHY DO WE NEED TO CONSERVE FUEL? For a long time after our country was settled, no one even wondered about our supplies of fuel. There had always been plenty of wood, and there seemed to be enough coal to last forever. Oil and gas were first used mostly for lighting. There seemed to be enough of these fuels, too. However, more and more fuel was burned each year. At last, about fifty years ago, a few people began to realize that we were faced with a serious problem. Our forests were disappearing fast. And our supplies of coal, oil, and natural gas were being used up rapidly. How long would our supplies of fuel last?

Scientists have studied this problem for some time, but they have not yet found an answer. No one really knows just how long our supplies of fuel will last. But scientists are sure that, except for wood, new supplies of our fuels are being made very slowly, if at all. The conditions under which coal, oil, and natural gas were made no longer exist on the earth. So when our supplies of these fuels are used up, there will probably be no more.

If we keep on using as much coal as we do now, our supply may last several thousand years. But if we use more coal, the supply will not last so long. On the other hand, if we use less coal, the supply will last longer. Before our supply of coal is used up, our supplies of oil and natural gas will probably be gone. Some scientists think



This graph shows the things we use to give us heat and other forms of energy. Which ones can be replaced when they have been used? Which ones cannot?



Millions of gallons of oil were wasted in the days when oil was allowed to gush from newly drilled wells. Drilling wells very close together wasted oil, too.

that our supplies of oil and natural gas may last less than fifty years. Of course, this depends on how fast we use these fuels. If new supplies of oil and natural gas are found, these fuels may last much longer.

Right now, we cannot tell how much fuel will be needed in the future or even what kind of fuel will be used most. Perhaps scientists will discover how to harness atomic energy or the energy of the sun to run huge electric power plants and to drive our trains and ships. But no matter what happens, one thing seems fairly certain: We will keep on using our supplies of coal, oil, and natural gas as long as they last.

Our problem is to learn how to get the most from these fuels with the least waste. In other words, we must learn to conserve the fuels that we need. To some people, conservation means not using materials. But that is a foolish and impractical idea. Real conservation is using materials wisely. What you have learned about fire will help you understand how we can conserve fuel.

Wells no longer gush, and new oil fields are laid out with the wells carefully spaced. These ways of conserving oil will help make our supply last longer.

SELF-TESTING EXERCISES

1 Why can we not be sure how long our supplies of fuel will last?
2 **a** Which of our fuels will probably be used up first?
  b Which of our fuels will probably last longest?
3 **a** Explain in your own words what conservation means.
  b Why must we conserve our supplies of fuel?

WHAT CAN WE DO TO CONSERVE FUEL? To make our supplies of coal, oil, and natural gas last longer, there are two main things that we can do: (1) We can make better use of these fuels. (2) We can use something else in place of them. For many years, much fuel was wasted in getting it out of the earth. Almost half of the coal and nearly two thirds of the oil were left in the ground. Huge amounts of natural gas escaped into the air. But better methods of getting these fuels out of the earth have helped reduce this kind of waste. Now it is up to us to make the best use of the fuels after they have been produced.

How is fuel being wasted here? How could this waste be prevented?

One way to do this is to get more heat from the fuel that we burn. You know that tiny bits of unburned carbon make black smoke and soot. So they are sure signs that fuel is being wasted. We have to burn more fuel to get the heat that we need. But if we keep fires from smoking and making soot, we can get just as much heat from less fuel. When a fire has enough oxygen, the fuel burns better and gives more heat. By carefully regulating the fire in our stoves and furnaces, we can help conserve fuel.

Another way to make better use of our fuels is to keep heat from being wasted. Many people keep their homes warmer than necessary, and they heat rooms that they seldom use. By keeping their homes a little cooler and shutting off unused rooms, these people could help save fuel. A great deal of heat goes out through the roofs, walls, windows, and doors in our buildings. More fuel is burned to make up for the heat that is lost. To reduce this loss of heat, there are several things that we can do. Special materials can be put in the roof and walls to keep heat in. The cracks around windows and doors can be closed so that hot air cannot get out and cold air cannot get in. Storm sash or double glass can also be put in the windows and doors.

Fuel can be conserved by not wasting heat in cooking. Heat goes out through the top and sides of an oven. It is also lost when the oven door is open. A small pan set over a large burner wastes heat around the sides. Too hot a fire is often used in cooking. You

know that water in an open pan cannot be heated hotter than its boiling point, but many people do not know this. They turn up the burner and think that they are making the water hotter. Of course they are just wasting fuel. The extra heat only changes more water to steam. However, if the pan is tightly covered to make a pressure cooker, the water will keep on getting hotter. Cooking in pressure cookers helps conserve fuel, because less heat is wasted.

The other main thing we can do to conserve coal, oil, and natural gas is to use something else. But that is often impractical or too costly. Of course, where wood is cheap and easy to get, we can use it as a fuel. We can make wood and grain into alcohol, which burns with a hot flame. However, alcohol costs more to use than the fuels that we get out of the earth. Moving water and even moving air can be used to turn machines that produce electric current. The electric current can then be used to provide heat. But where electric current is produced by burning coal, using electric current does not help conserve fuel.

Scientists have developed a new material made of glass fibers. It is not hard and stiff as you might think, but it is soft enough to be forced into the cracks around windows. How does filling these cracks help save fuel?

Instruments to measure the draft, the temperature of the smoke stack, and the amount of carbon dioxide coming from the fire give new ways of finding out whether fuel is being wasted.

For a long time, scientists have known that the earth gets huge amounts of heat from the sun. Homes and buildings have been made so that the sun helps heat them on clear days. So far, no good way has been found to store this heat for use on cloudy days or at night. The atomic energy stored in all materials would also provide huge amounts of heat. But scientists have not yet discovered how to control this energy so that it can be used cheaply and safely. For many years, we will probably get most of the heat that we need from the fire of burning fuels. If we are wise, we will try to make the best use of the coal, oil, and natural gas that we now have.

SELF-TESTING EXERCISES

1 **a** What are the two main things that can be done to conserve fuel?
  b Which one is usually easier or cheaper to do? Why?
2 How can you conserve fuel by carefully regulating a fire?
3 **a** Explain why saving heat also saves fuel.
  b Give as many ways to save heat as you can.

PROBLEMS TO SOLVE

1 Do you think that fuel is being wasted in your community? Give your reasons.
2 **a** What methods of fuel conservation are being used in your community?
  b What other methods could be used to help conserve fuel?

3 Make a list of ways in which fuel could be saved in your home. Then explain why each way would help save fuel.

4 Turning off electric lights that are not needed can help conserve fuel. How is this possible?

5 Chemists know how to make gasoline from either coal or natural gas. If our supply of oil runs out, which do you think they should use to make gasoline? Why?

6 How can you tell if a gas or oil stove used for cooking is wasting fuel? Explain your answer.

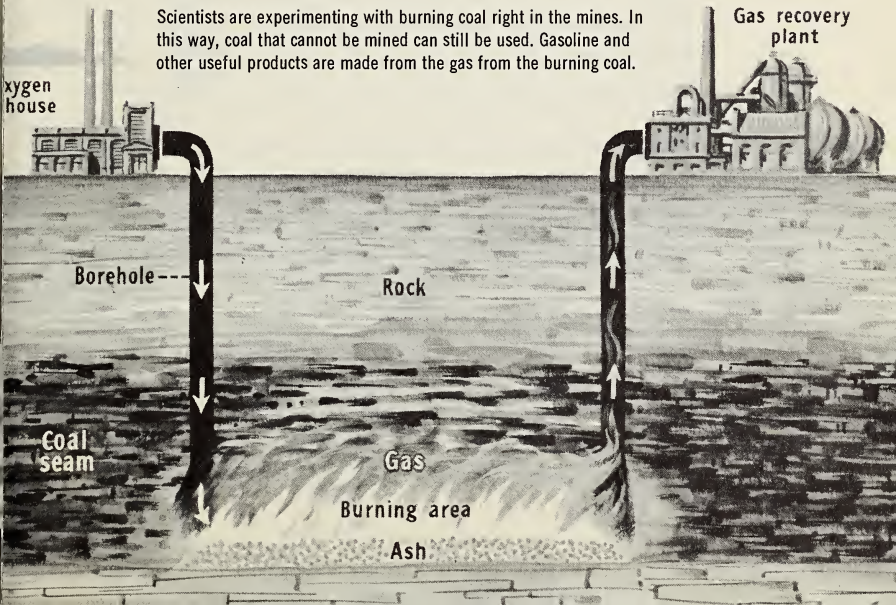
SUMMARY EXERCISES

1 Make a list of the big ideas that you learned in this unit. Write them as complete sentences.

2 Show that you know what the following words mean: oxide, oxidize, oxidation, combustion, combustible, incombustible, bituminous, anthracite, kindling temperature, spontaneous combustion.

ADDITIONAL ACTIVITIES

1 Examine a photoflash bulb used by photographers. The bulb is filled with pure oxygen. What is the combustible material? How is it set on fire? What is the white material left inside the bulb after it has been used?


Scientists are experimenting with burning coal right in the mines. In this way, coal that cannot be mined can still be used. Gasoline and other useful products are made from the gas from the burning coal.
Gas recovery plant
xygen house
Borehole
Rock
Coal seam
Gas
Burning area
Ash

The men are loading peat, a kind of fuel. From reference books, find out as much as you can about peat. How is it formed? How is it used?

2 Light a gas burner. Then bring a piece of iron screen or wire gauze down on the flame. Why does the flame not go through the screen? Turn off the burner and then turn it on again. Hold the screen over the burner and bring a lighted match into the gas above the screen. What happens this time? Why?

3 Test the kindling temperature of sulphur, a match head, a piece of wood, and a piece of paper. Set them all on a metal plate over a flame. Which has the lowest kindling temperature? The highest kindling temperature? How do you know?

4 Light a match and hold it with the head up. Notice how it burns. Then light another match of the same kind and hold it with the head down. Does it burn faster or slower than before? Explain.

5 Make a drawing of the furnace or stove in your home. Label all the important parts including the controls.

6 Collect samples of the different kinds of fuels used in your community. Find out which ones give the most heat for the least money.

7 Make a collection of products that are made from coal and petroleum. Display these products so that they can be used for study by your class.

8 Keep a record of fires reported in the local newspaper. Note the cause and the amount of damage for each fire.

9 Find out how the fire extinguishers in your school building work.

Kind of extinguisher	Materials used	Kinds of fires
Dry chemical	Dry, powdered sodium bicarbonate and other dry chemicals	Electrical equipment Flammable liquids
Water Anti-freeze	Calcium chloride and other chemicals dissolved in water	Wood Rubbish Fabrics Paper
Liquid chemical	Methyl bromide and other chemicals	Wood, paper, etc. Electrical equipment Gasoline Naphtha Grease, oil

These three kinds of fire extinguishers are different from the ones on page 213. Study the table and then explain why each kind is used.

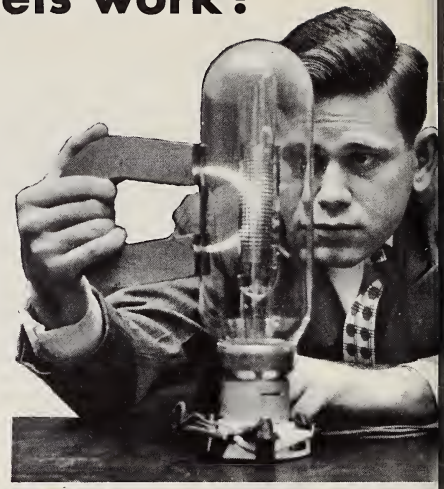
10 Prepare a set of rules for helping prevent and extinguish fires. Then put the rules on a large sheet of cardboard that can be put in your classroom.

11 Is smoke a nuisance in your community? If so, what is being done to get rid of the smoke?

12 In reference books, read about the following: lignite; coal mining; drilling oil and natural gas wells; refining petroleum; fire-fighting; forest fires.

How do magnets work?

For hundreds of years, people have used magnets. Magnets helped Columbus and other early explorers find their way across the oceans to new lands. Today they still help us find our way at sea, on land, and in the air. And they do many other things for us, too.



UNIT 7

Magnets lift heavy loads, make motors run, and do many smaller jobs in homes and workshops. As you learn about magnets in this unit, look about you for other examples of magnets at work

LOOKING AHEAD TO UNIT 7

Nearly everyone knows something about magnets. You have probably used a magnet to pick up pins, tacks, and other things made of iron or steel. Perhaps you have made a toy boat that would follow a magnet held in your hand, or you may have used a magnet to do tricks. The kind of magnet that you used was probably a straight bar of steel or a piece of steel shaped like a U or a horseshoe. Magnets of this kind have been made for many years. But long before they were used, people knew about the strange force called magnetism.

Just when and how magnetism was discovered, we do not know. Hundreds of years ago, people learned that a brown rock would pull on pieces of iron and hold them to it. Different stories are told about how this kind of rock was found. One old story tells about a young shepherd named Magnes. As he was watching his sheep, he set the iron tip of his wooden shepherd's staff down on a rock. When he tried to lift the staff, the iron tip stuck to the rock. He had to pull very hard to get it free. According to this story, his friends called the rock a magnet from Magnes, the shepherd's name. But no one really knows how or when magnetism was discovered.

Another old story tells about a wonderful mountain near the sea. When ships tried to sail past this mountain, they fell apart. The mountain was a powerful magnet that pulled the iron nails out of the ships. Soldiers wearing iron armor were pulled against the mountain, too. It held them so tightly that they could not get away. Of course, a mountain like this has never been found by modern explorers. But even though we do not believe these old stories, they show that people knew about magnetism long ago.

For many years, people thought that magnetism was just a strange force which one kind of rock had. It was interesting, but it was not really useful. At last, someone discovered that a piece of iron would act like a magnet if it was rubbed on the rock. Then a great discovery was made. If a magnet made of iron was set on a piece of wood floating in water, the magnet would turn until it pointed toward the north and the south. This was the first compass used to show directions. The rock used to make the iron mag-

In the days of Queen Elizabeth of England, Sir William Gilbert did some of his first real experiments with magnets. Here he is showing some of his experiments to the Queen.

net in the compass was called lodestone, which means leading stone. Scientists have found that lodestone is made of a kind of iron ore. They call this ore *magnetite* (mag′ ni tīt).

The compass is one of the most important inventions ever made, but for a long time no other uses for magnets were discovered. Magnets were so weak that they could move only small pieces of iron. Finally, scientists discovered how to make much stronger magnets by using electric current. They also learned how to use electric current to make electromagnets, whose force can be turned on or off. From then on, many new uses for magnets were found.

Telephone receivers, loud-speakers, and speedometers all have magnets in them. So do electric bells and buzzers. In every electric motor or generator, you will find magnets. They control the warning signals on railroads, and they pick up nails on our highways. Doctors often use magnets to get tiny bits of iron out of a person's eyes or throat. In these and many other ways, magnets are used every day.

As you study this unit, you will learn some of the important facts that scientists have discovered about magnets. You will also find answers to such questions as these: What materials does a magnet attract? Where is the force of a magnet? How can one magnet be used to make another? How are electromagnets controlled? How does a compass show directions? How do we explain magnetism?

Lodestone

Bar magnet

Horseshoe magnet

U-magnet

You may see magnets in any of these shapes.

1 What can magnets do?

WHAT MATERIALS DOES A MAGNET ATTRACT? If you ever used a magnet, you soon discovered that it picks up or sticks to some things but not others. We say that a magnet attracts, or pulls toward itself, certain materials. To find out what these materials are, do Experiment 1.

Experiment 1 What materials are attracted by a magnet?

1 Test different things to find out whether they are attracted by a magnet.

2 Make a list of the things that are attracted by a magnet. What materials are these things made of?

3 Can you feel the force of a magnet when it attracts a material? Can you feel its force when you pull the material off the magnet?

4 Did you have to touch a material with the magnet to attract it?

Only a few materials are attracted by a magnet. We call them magnetic materials. Most materials are non-magnetic. They are not attracted by a magnet. Iron and steel are the commonest magnetic materials. Steel is an *alloy* (al′ oi) that is mostly iron with a little carbon and some other materials in it. An alloy is a metal

made by melting together two or more metals, or a metal and some other material. Besides iron and steel, a few other materials, such as nickel and cobalt, are magnetic. However, pure nickel and pure cobalt are seldom used to make things. They are usually mixed with some other metal such as iron or copper to form alloys. Some of these alloys are magnetic materials, and others are non-magnetic.

In Experiment 1, you used a magnet to find out what materials are magnetic. When a material was attracted by the magnet, you could feel the force. You could also feel the force when you tried to pull the magnetic material away from the magnet. To get the material off the magnet, you had to pull harder than the magnet was pulling. So you can tell that a magnet has force. It pulls magnetic materials toward itself and then holds them.

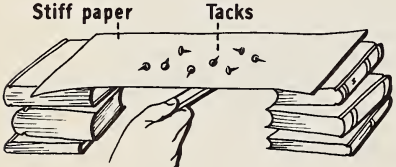
SELF-TESTING EXERCISES

1 How can you find out whether a material is magnetic or not?
2 Name four magnetic materials and four non-magnetic materials.
3 What do we mean by an alloy?
4 How do you know that a magnet has force?

The tiny magnet that this scientist is holding weighs less than an ounce. But it is so strong that it can hold up a weight 4000 times heavier than the magnet.

WHAT MATERIALS DOES THE FORCE OF A MAGNET PASS THROUGH? You know that the force of your muscles cannot move anything unless you touch it in some way. But as you were doing Experiment 1, you noticed a surprising fact about the force of a magnet. When you brought the magnet near a small piece of iron or steel, the piece jumped to the magnet. So a magnet can attract magnetic materials without even touching them. The force of a magnet passes right through the air! Can the force of a magnet pass through other materials? Experiment 2 will help you find the answer to this question.

Experiment 2 What materials can the force of a magnet pass through?



1 Move the magnet around under the paper. What happens to the tacks? What does this show about the force of a magnet?

2 Try the same experiment using sheets of glass, thin wood, aluminum, copper, brass, zinc, iron, and steel. What happens?

3 Through what materials does the force of a magnet easily pass? Are they magnetic or non-magnetic materials?

4 What materials seem to cut off the force of a magnet?

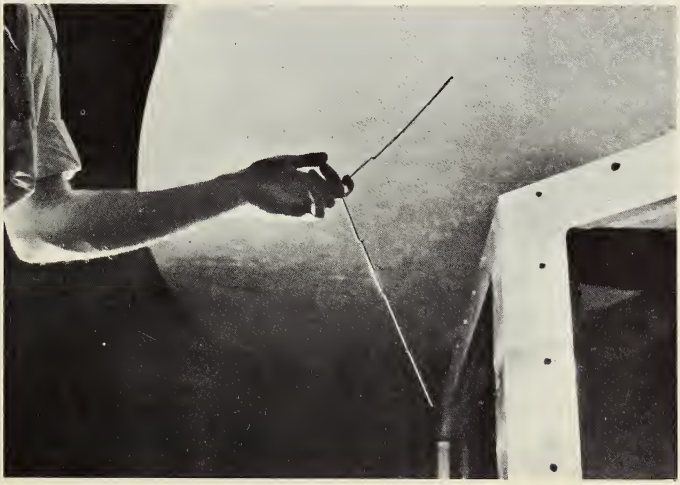
After carefully doing many experiments, scientists have discovered that the force of a magnet can pass through any material. However, it passes through some materials more easily than through others. If you did Experiment 2, you know that this is true. The force of a magnet passes easily through paper, glass, wood, aluminum, copper, zinc, and brass. All these materials are non-magnetic. From many experiments, scientists have learned that the force of a magnet passes quite easily through any non-magnetic material. As you might expect, the thinner the material is, the more easily the force passes through it.

However, the force of a magnet does not pass easily through magnetic materials. Even a thin sheet of iron or steel can keep nearly all the force from passing through it. So a sheet of iron or steel is often used as a screen between a magnet and magnetic materials. Most of the force spreads out in the iron or steel and then goes right back into the magnet. The force that passes through the screen is usually too weak to be noticed. But by using delicate instruments, scientists can tell that some force always passes through any magnetic material. No material has ever been found that will cut off all the force of a magnet.

SELF-TESTING EXERCISES

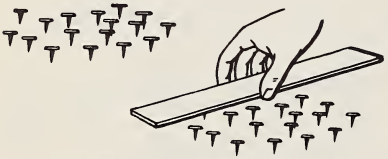
1 How can you find out whether the force of a magnet will pass through a material?
2 Is this statement correct? *The force of a magnet can pass through non-magnetic materials but not through magnetic materials.* Explain your answer.
3 How does a sheet of iron or steel act as a screen for a magnet?

Someone is pulling on this chain of nails between the two ends of a huge magnet. How do you think the nails can stand up in the air like this with nothing holding the ends of the chain?



WHERE IS THE FORCE OF A MAGNET? You know that a magnet has force, because it can attract magnetic materials. And you have learned that the force of a magnet can pass through any material. Yet you cannot see this force. You can only see what it does. You cannot even feel the force unless a magnet is near a magnetic material. The closer the material is to the magnet, the stronger the force seems to be. But where is this force? Is it inside the magnet? Is it outside the magnet? Or both? To find the answers to these questions, you can do some experiments. Experiment 3 will help you discover where the force of a magnet is strongest.

Experiment 3 Where is the force of a magnet strongest?



1 Spread the tacks evenly. Then lay the bar magnet on the tacks.

2 Lift the bar magnet. To what parts of the magnet do most of the tacks stick?

3 Repeat the experiment using a U-magnet, a horseshoe magnet, and a lodestone. What happens with each magnet?

4 Try the experiment again using iron filings, paper clips, and other magnetic materials. What happens? Do you get the same results as you did before?

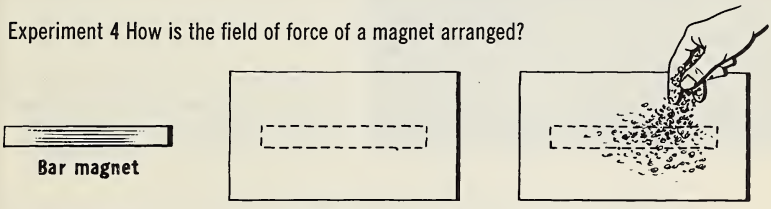
5 Where is the force of a magnet strongest? How do you know?

No matter what shape of magnet is used, more tacks stick to some parts of the magnet than to other parts. So the force of a magnet must be stronger in some places than in others. The places where the force is strongest are called the poles of the magnet. The poles are usually near the ends of a magnet, and every magnet has two poles.

In Experiment 1, you noticed that a magnet attracts magnetic materials even before it touches them. And in Experiment 2, you found that the force of a magnet can easily pass through many

materials. Experiment 3 showed you that the force of a magnet is strongest at its poles. The force reaches out from the magnet into the space around it. This space where the force acts is called the *field of force* of the magnet, or its *magnetic field*. Of course, you cannot really see the field of force of a magnet. But you can learn what it is like by doing Experiment 4.

Experiment 4 How is the field of force of a magnet arranged?



1 Lay a piece of paper over the bar magnet. Sprinkle iron filings on the paper. Tap the paper gently. What happens?

2 Look carefully at the pattern of lines. Do the lines reach out from the poles of the magnet in all directions? Do they pass through the space around the magnet from one pole to the other? Where are the lines closest together? What does this show you about the force of a magnet?

3 Repeat the experiment using a U-magnet and a horseshoe magnet. What pattern of lines does each magnet make?

4 What do you think the pattern of lines would look like if you used a stronger magnet? A weaker magnet?

5 Try an experiment to find out whether your predictions are correct. What do you discover in this experiment?

In the field of force of a magnet, iron filings arrange themselves in a pattern. This pattern is made up of a series of lines. We call them *lines of force,* because the force of a magnet seems to act along these lines. At the poles of a magnet, the lines of force are closest together. This shows that the force of a magnet is strongest at its poles. The lines of force pass between the poles through the space around a magnet, and they reach out in all directions. The stronger a magnet is, the farther the lines of force reach and the closer together they are. The pattern of lines shows us how the field of force around a magnet is arranged.

Though the scientist is pulling as hard as he can, he cannot pull the sheet of metal from between the poles of a giant magnet. What things does this show you about the force of a magnet?

Look at the upper picture on page 224. Here is a new way of showing the lines of force of a magnet. When this horseshoe magnet is held close to a special kind of tube, the lines of force around the poles of the magnet show up as a path of very bright light.

SELF-TESTING EXERCISES

1 What do we mean by the poles of a magnet?
2 Explain what is meant by the field of force of a magnet.
3 Do lines of force reach out in all directions from the poles of a magnet? Or are the lines of force in a flat sheet like the paper on which iron filings were sprinkled? Give reasons for your answer.
4 State two ways in which the lines of force around a strong magnet are different from those around a weaker magnet.
5 Draw pictures showing how the lines of force are arranged in the magnetic field around a bar magnet and a U-magnet.

PROBLEMS TO SOLVE

1 Explain why a magnet will pick up some straight pins but not others, even though the pins may all look alike.
2 One day a piece of metal flew into a workman's eye. A doctor could not pull the metal out with a magnet. Why do you think the magnet did not pull out the metal?

3 An old story tells about a thief who stole coins from people's pockets with a magnet. Do you think this story is true? Why?

4 Tin is a non-magnetic material, but a magnet will attract a tin can. How can you explain this?

5 A boy put a cork on a piece of paper. As he moved a magnet around under the paper, the cork followed the magnet. How do you suppose the boy made the cork move?

6 Nickel is a magnetic material, but the five-cent piece that we call a nickel is not attracted by a magnet. Why?

7 Do you think that air is a magnetic material or a non-magnetic material? Explain your answer.

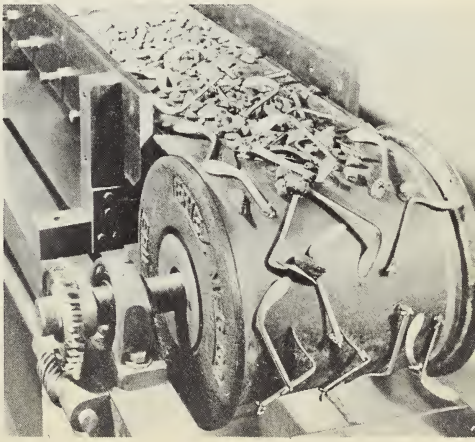
8 When a piece of glass was put over a magnet, the magnet failed to attract bits of iron and steel through the glass. How can you explain this?

9 If you worked in a factory where powerful magnets were used, how could you keep the magnets from affecting the steel spring in your watch? Explain your answer.

10 When a U-magnet or a horseshoe magnet is not in use, a piece of iron called a keeper is put across the ends. If the keeper is left on, will the magnet pick up magnetic materials just as well? Why?

11 Do you think that a lodestone has poles? Give reasons for your answer.

12 Suppose that you want to find out which of two bar magnets is the stronger. How could you do it? Think of several different ways and tell why each way would work.

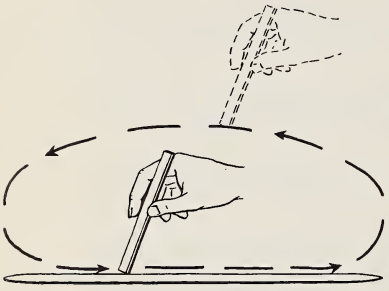


In this machine, a belt passes over a large magnet. Use what you have learned to explain how the magnet separates materials.

2 How can we make magnets?

HOW ARE PERMANENT MAGNETS MADE? Lodestones are the only natural magnets that we have. All of our other magnets must be made. Of course, we can use a lodestone to magnetize a piece of iron or steel, or to make it into a magnet. Then we can use the new magnet to magnetize other pieces of iron or steel. Experiment 5 shows you how one magnet can be used to make another magnet.

Experiment 5 How can one magnet be used to make another magnet?



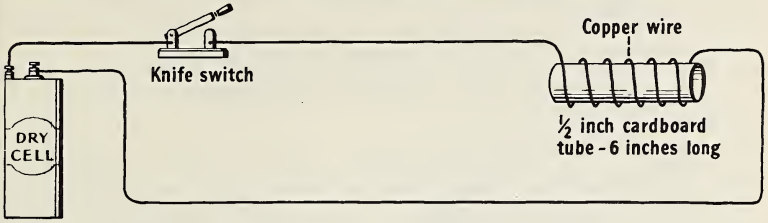
1 How can you test a steel nail or knitting needle to find out whether it is a magnet? Try it and see.

2 Stroke the nail or knitting needle with one end of a bar magnet. Be careful to stroke it only in one direction and to lift your hand between strokes. Now test it again to see whether it is a magnet. What do you discover?

3 How do you think you could make the magnet stronger? Try it and see what happens.

To magnetize a piece of iron or steel, you bring it into the field of force of a magnet. The magnet that you made will keep its magnetism for a long time. So it is called a permanent magnet. The metal magnets that you have been using to do the experiments in this unit are all permanent magnets. These magnets that we buy are not made by stroking them with another magnet. Only weak magnets can be made in this way. Much stronger permanent magnets are made by using an electric current. Experiment 6 shows you how an electric current can be used to make a permanent magnet.

Experiment 6 How can an electric current be used to make a permanent magnet?



1 Wind about 200 turns of No. 18 or No. 22 covered copper wire around the cardboard tube. Then connect the coil of wire to the switch and dry cell as shown in the picture. The switch turns the current on or off.

2 Test a steel nail or knitting needle to find out whether it is a magnet. Then put it inside the coil of wire wound around the cardboard tube. Close the switch and quickly open it again. Test the piece of steel to find out whether it is now a magnet. What do you find?

3 How could you find out whether the magnet that you made in this experiment is stronger than the one that you made in Experiment 5? Try it and see what happens. Which magnet is stronger?

When an electric current flows through a wire, the wire is surrounded by a magnetic field. We can use this field of force to magnetize pieces of iron or steel. Iron can be magnetized more easily than steel, but iron soon loses its magnetism and must be magnetized again. So permanent magnets that we buy are made of steel or some other magnetic alloy that keeps its magnetism for a long time. They are made by putting the steel or other magnetic alloy in a coil of wire through which a very strong electric current is sent.

Certain important alloys used for making permanent magnets are called alnico. The name is made up from the chemical symbols for three of the elements in the alloys: aluminum (Al), nickel (Ni), and cobalt (Co). Besides these elements, alnico also contains different amounts of manganese, silicon, iron, and sometimes copper. Some alnico magnets are so strong that they will lift more than 4000 times their own weight. The magnet shown in the pictures on page 229 is an alnico magnet.

SELF-TESTING EXERCISES

1 What do we mean by a permanent magnet?

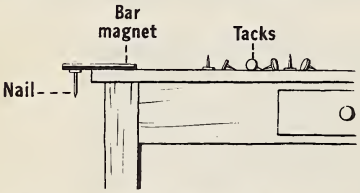
2 **a** State two ways in which permanent magnets can be made.
b Which way is used to make the permanent magnets that we buy?

3 Why is iron not used for permanent magnets?

4 Name two alloys that are used to make permanent magnets.

HOW ARE TEMPORARY MAGNETS MADE? Permanent magnets are useful for many purposes. They can be made quite strong, and they keep their magnetism for a long time. However, their magnetism cannot be turned on or off as we need it. We often want a temporary magnet, whose force we can control. Because iron soon loses its magnetism, we can use it for temporary magnets. Experiment 7 shows you how one kind of temporary magnet can be made.

Experiment 7 How can you make a temporary magnet?



1 Test an iron nail to find out whether it is a magnet. Then hang the nail from one end of a bar magnet.

2 How can you tell whether the nail is now a magnet? Try it and see what happens.

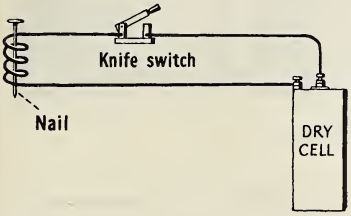
3 Take the nail off the bar magnet and test it again. Is the nail still a magnet? How do you know?

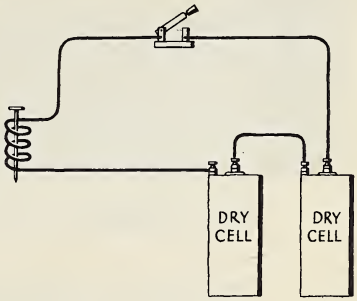
4 Try the experiment again, but keep the nail from actually touching the bar magnet. What happens this time? What does this show?

When a piece of iron is in the field of force of a magnet, the iron is a magnet, too. But when the field of force is removed, the iron quickly loses its magnetism. It stays magnetized only while it is in a magnetic field. Temporary magnets are usually made of iron or some special magnetic alloy that does not keep its magnetism. The weak temporary magnet that you made is not very handy to use. You can make a much better kind of temporary

magnet by using an electric current. This kind is called an electromagnet. Experiment 8 shows how an electromagnet is made.

Experiment 8 How can you make an electromagnet?





1 Wind about 25 turns of No. 18 or No. 22 covered copper wire around an iron nail. Then connect the coil of wire to the switch and dry cell as shown in the picture.

2 Test the nail to find out whether it is a magnet. Close the switch and again test the nail. What do you discover?

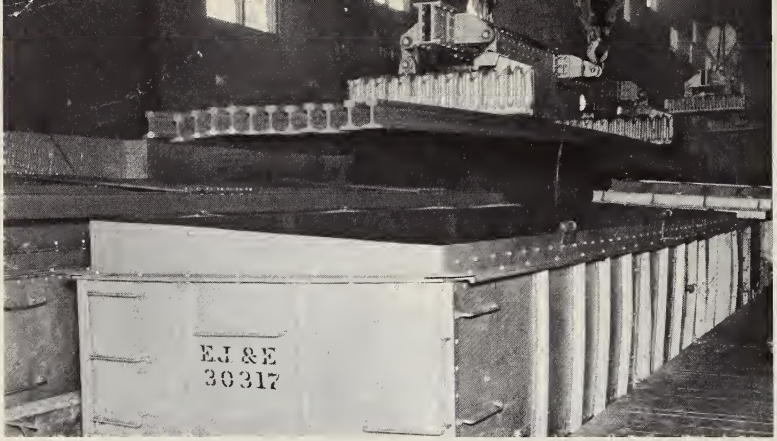
3 Open the switch and then test the nail. Is it still a magnet?

4 Wind about 25 more turns of the same wire around the nail. Then repeat the experiment. Is the magnet stronger than it was before? How do you know?

5 Connect another dry cell to the coil of wire as shown in the picture. Then try the experiment again. Is the magnet even stronger than before? How can you tell?

6 What are two ways of making an electromagnet stronger?

You can see that an electromagnet is just a coil of wire wound around a core. The core is usually made of iron. When the ends of the wire are connected to a dry cell, there is a path through which an electric current can flow. We call this path a circuit, because the current goes all the way around it. As the current flows through the circuit, it causes a magnetic field around the wire. The magnetic field is strongest where the wire is wound into a coil, and it instantly magnetizes the iron core. The core becomes a magnet, but it is only a temporary magnet. When one



How is an electromagnet used to load rails into a freight car?

end of the wire is disconnected from the dry cell, the circuit is broken. The current stops at once, and the magnetic field around the wire disappears. The coil instantly loses its magnetism, and so does the core. It is no longer a magnet.

An electric current flowing through even one turn of wire will cause a little magnetism in the core. As more turns of wire are added, the magnetism increases. A stronger current also increases the magnetism. So there are two ways to make an electromagnet stronger: (1) Wind more turns of wire around the core. (2) Send more current through the coil. Both ways are used to make very strong electromagnets. Many turns of wire are wound around the core, and a strong current is sent through the coil. But no matter how strong an electromagnet is, its force can be easily and quickly controlled by turning the current on or off. An electromagnet is a magnet only when the current is flowing through the coil around the core.

SELF-TESTING EXERCISES

1 How is a temporary magnet different from a permanent magnet?
2 Why is iron often used to make temporary magnets?
3 In your own words, tell how an electromagnet is made and explain how it works.
4 State two ways of making an electromagnet stronger.

PROBLEMS TO SOLVE

1 After a time, a permanent magnet may become weaker. How can you make it strong again?

2 **a** Some tack hammers have heads that are magnets. How would such a hammer keep you from hitting your fingers when you are driving tacks into wood?

b Do you think that the head of the hammer is made of iron or of steel? Give reasons for your answer.

3 The brakes on some streetcars are magnets that help stop the car by pressing tightly against the steel tracks. Are permanent magnets or electromagnets used in these brakes? Explain your answer.

4 Two bars of metal look exactly alike, but one is iron and the other steel. How could you use magnetism to find out which one is iron and which one is steel?

5 **a** What advantages does an electromagnet have over a permanent magnet?

b What advantages does a permanent magnet have?

6 What would happen if you used a steel core in an electromagnet?

On model trains, one car can be uncoupled from another by pressing a button. Study the picture and explain how this can be done.

3

How does a compass show directions?

WHY DOES A COMPASS POINT TOWARD THE NORTH? A compass has a magnet that can turn freely and show directions. Long ago, people used a very simple compass. It was just a small bar of magnetized iron floating on a piece of wood in a bowl of water. The iron soon lost its magnetism, and then it had to be magnetized again. Today, we have much better compasses. You may have seen the large compasses used by surveyors or navigators of ships and airplanes. Perhaps you have even used a small pocket compass like the ones that Boy Scouts carry to find their way in the woods.

Before you can tell directions with a compass, you must be sure that there is no iron or steel near it. You set the compass in the palm of your hand or on any level surface. Then you wait until the needle stops swinging back and forth. This needle is a permanent magnet. One end of the needle is marked in some special way. It may be blue, black, or silver-colored. When the needle stops swinging, this end will point toward the north and the other end toward the south. The card under the needle has printed letters that stand for the different directions. If you turn the case of the compass until the marked end of the needle is over the letter N, you can easily find all the directions. N stands for north, S for south, and so on. NE, or northeast, is halfway between north and east. SW, or southwest, is halfway between south and west. You can easily find out what the other letters mean.

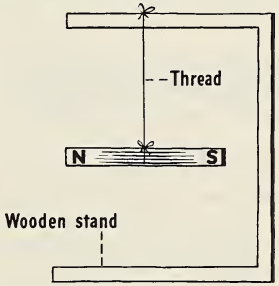
The north-pointing pole of the needle of this pocket compass has some fine wires wrapped around it.

As you can see, a compass is not hard to use. But how does a compass show directions? Why does one end of the needle point toward the north and the other end toward the south? To answer these questions, you must learn some more facts about magnets. You already know that the force of a magnet can pass through any material—even air. You have learned that every magnet has two poles, which are usually near the ends of the magnet. While you were working with magnets, you must have noticed that the ends of some magnets are marked. One end has N on it and the other end S. Perhaps you guessed that N stands for north and S for south. But you probably wondered why the ends of the magnets were marked in this way. Experiment 9 will help you find out.

Experiment 9 What happens when a magnet is free to turn?

1 Be sure that the magnet is free to turn. Do not have any other magnets or any pieces of iron and steel near the hanging magnet. Why?

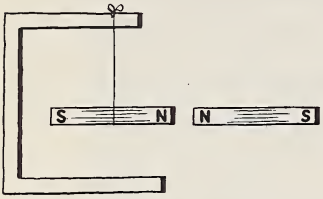
2 When the magnet stops swinging, notice in what direction each end points. In what direction does the end marked N point? In what direction does the end marked S point? What instrument have you made?



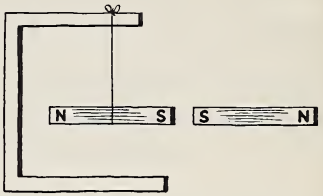
When a magnet is free to turn, one end will point toward the north and the other end toward the south. So we can give each pole of the magnet a name. The pole near the end that points toward the north is called the north-seeking pole, or the north pole, or the N pole. The pole near the end that points toward the south is called the south-seeking pole, or the south pole, or the S pole. Whether the poles of a magnet are marked or not, every magnet has an N pole and an S pole. The marked end of a compass needle is an N pole and the other end an S pole. You know that either pole of a magnet attracts iron or steel. But how

do the poles of one magnet act toward the poles of another magnet? By doing Experiment 10, you can find the answer to this question.

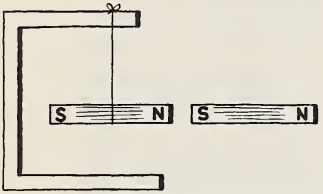
Experiment **10** How do the poles of magnets act toward each other?



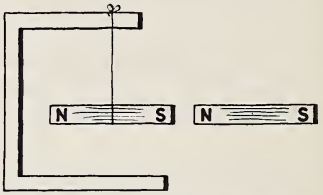
1 What happens when the magnets are like this?



2 What happens when the magnets are like this?



3 What happens when the magnets are like this?



4 What happens when the magnets are like this?

5 What does this experiment show you about the poles of magnets?

6 What do you think would happen if you used U-magnets or horseshoe magnets?

7 Try it and see what happens.

8 Do you get the same results as before?

Two N poles repel each other, or push each other away. Two S poles also repel each other. However, an N pole and an S pole attract each other. Many experiments have shown that the poles of magnets always act toward each other in this way. So we can state two rules about the poles of magnets: (1) *Like* poles of magnets *repel* each other. (2) *Unlike* poles of magnets *attract* each other. By using these two rules, you can explain what happens in Experiment 11.

Experiment **11** How does a magnetized needle act near a magnet?

1 Strongly magnetize the steel needle. How can you do this?

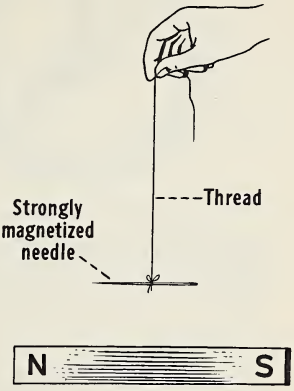
2 Hang the needle from a thread as shown in the picture. Hold the thread so that the needle is about 2 inches above the middle of the bar magnet. What happens?

3 Move the needle over one pole of the magnet and then over the other. What happens now?

4 Move the needle all around the magnet and watch what it does. How does it act as you move it?

5 Draw a diagram showing how the needle points all around the magnet.

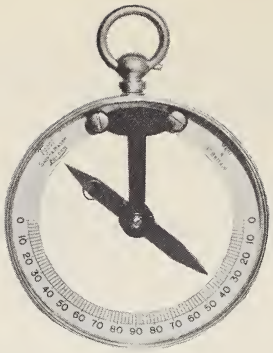
6 What does your diagram show? Does the needle seem to follow the lines of force that you noticed in Experiment 4?



7 If you put the magnet under a piece of paper, how could you use the needle to find the poles of the magnet? Try it and see what happens.

A magnetized needle is a small magnet. It seems to follow the lines of force around a larger magnet. So you can use the needle to explore the field of force of a magnet and find the poles. Over the N pole of the magnet, the S pole of the needle points downward. Over the S pole of the magnet, the N pole of the needle points downward. Between the poles of the magnet, the needle points toward the N pole or the S pole, whichever is nearer. Now what does all this have to do with how a compass shows directions?

Scientists have a special kind of compass called a *dipping needle*. Like the magnetized needle that you used in Experiment 11, a dipping needle can point downward or stand level. In different places on the earth, dipping needles act much the same as the magnetized needle does around a magnet. In the far north, scientists found an area where the N pole of a dipping needle points straight downward. In the far south, they found an area



An instrument having a dipping needle can be used to locate buried metal pipes. Someone carries the instrument over the area where the pipe probably is. How can he tell when he is walking over the pipe?

where the S pole of a dipping needle points straight downward. Between these areas, the needle does not dip so much. Near the equator, the needle stands level.

There seems to be only one explanation for the way in which dipping needles and other compasses act. All the experiments that scientists have tried seem to show that this explanation must be correct. The earth itself acts like a huge magnet! Like other magnets, the earth has a magnetic field. Dipping needles and other compasses show the direction of the lines of force in the earth's magnetic field. This magnetic field has two poles, which are called the earth's magnetic poles. The pole in the far north seems to attract the N pole of a compass needle, and the pole in the far south seems to attract the S pole. You can now understand how a compass shows directions.

However, you have learned that like poles of magnets repel each other and unlike poles attract each other. Then why does the earth's north magnetic pole seem to attract the N pole of a compass needle? If you think about what you have learned, you can find the answer to this question. The earth's north magnetic pole is really an S pole! So you can see that the earth's south magnetic pole must really be an N pole, because it seems to attract the S pole of a compass needle.

SELF-TESTING EXERCISES

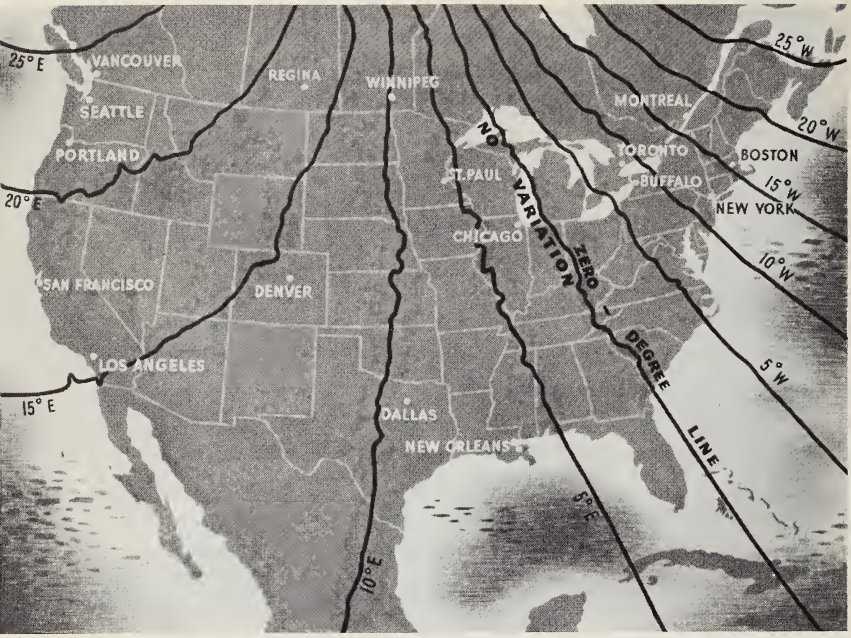
1 How can you use a compass to tell directions?
2 State the two rules about the poles of magnets.
3 Why does the marked end of a compass needle point toward the north?
4 How does a dipping needle help scientists find the earth's magnetic poles?
5 What kind of pole is the earth's north magnetic pole? Its south magnetic pole? Explain your answers.

WHY DOES A COMPASS NOT ALWAYS POINT TRUE NORTH? If you are lost in Maine and go north according to a compass, you will really travel a little northwest instead of true north, or exact north. If you are lost in Oregon and go north according to a compass, you will really travel a little northeast instead of true north. What is the reason for this? Why does a compass needle not always point true north, no matter where you are on the earth?

If you studied science before, you probably learned that the earth turns around an imaginary line called its axis. This axis runs through the center of the earth. One end of the axis is called the North Pole and the other end the South Pole. These are the earth's geographic poles. True north is the direction straight toward the North Pole.

By using a dipping needle, scientists found the earth's magnetic poles. The north magnetic pole is more than 1400 miles from the geographic North Pole, and the south magnetic pole is more than 1400 miles from the geographic South Pole. A compass needle points toward the earth's magnetic poles, not toward its geographic poles. Because the magnetic poles are far from the geographic poles, a compass needle does not always point true north.

Look at the map on page 248 and find the line marked "No Variation." It is also called the *zero-degree line*. Along this line a compass needle always points true north. The other lines show how many degrees away from true north a compass needle points at places on these lines. East of the zero-degree line, a compass needle points west of true north. West of the zero-degree line, it points east of true north. To find true north with a compass, you



The map shows where the zero-degree line, or the line of no variation, now runs through the United States and Canada.

must know how much to change a compass reading for the place where you are. In New York City, a compass points about 10 degrees west of true north. To find true north, the case of the compass is turned so that the needle points 10 degrees west of N on the card. Then N points true north.

Surveyors and navigators have tables and maps that show how much to change the compass reading at any place on the earth. New tables and maps must be made from time to time, because the earth's magnetic poles slowly change their positions. About 150 years ago, the zero-degree line crossed our country more than 500 miles east of where the line is now.

Because a magnetic compass does not always point true north, ships and airplanes often use a gyrocompass (jī′ rō kum′ pəs). Inside a gyrocompass, a wheel called a gyroscope (jī′ rə skōp) is kept

spinning by an electric motor. As long as the gyroscope is spinning, the gyrocompass points true north. However, a gyrocompass is usually much heavier and more costly than a magnetic compass. So a magnetic compass is still used for many purposes.

SELF-TESTING EXERCISES

1 What do we mean by true north?
2 Why does a magnetic compass not always point true north?
3 How can you find true north with a magnetic compass?
4 **a** What advantages does a gyrocompass have over a magnetic compass?
b What advantages does a magnetic compass have?

PROBLEMS TO SOLVE

1 Find the place where you live on the map on page 248. Does a compass point true north there? Or does it point east or west of true north? About how much?
2 If a compass always pointed true north, no matter where you used it on the earth, what would this tell you about the north magnetic pole? Explain your answer.

When aviators flew over the region where the north magnetic pole should be according to their charts, they found that the compass needle still pointed north. What did this tell them about the north magnetic pole?

The boy wants to find his way back to camp. What must he know before he can use his compass to help him?

3 When a compass was set on a table, the needle pointed east instead of north. The table was turned around, and then the needle pointed west. Explain.

4 **a** The case of a compass is never made of iron or steel. Why?
b What materials do you think are used to make a compass case? Give reasons for your answer.

5 How could you find out whether a steel rod is magnetized? Think of several ways and explain how each way would work.

6 If you examine maps published in different years, you may find that no two maps give exactly the same positions for the earth's magnetic poles. Would this mean that the maps are incorrect? Explain.

7 A piece of iron or steel becomes magnetized if it stands upright in one place for a long time. Why do you think this happens?

8 In what direction will a compass point at the geographic North Pole? Explain your answer.

9 A hunter is using a compass to find his way in the woods. What should he do with his gun while he is reading the compass? Why?

10 Suppose that you have a magnet whose poles are not marked. How could you use a compass to find the N pole and the S pole of the magnet?

11 An explorer accidentally discovered a huge deposit of iron ore with his compass. How do you think this happened?

4

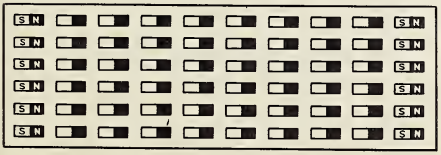
How do we explain magnetism?

You know that an ordinary piece of iron or steel is not a magnet. Yet it can be magnetized with a magnet or an electric current. Some change must take place inside the material when it is magnetized. Nobody knows exactly what happens, but scientists have a theory that explains the facts about magnetism. According to the theory of magnetism, every molecule of a magnetic material acts like a tiny magnet. So each molecule of the material has an N pole and an S pole.

If a magnetic material is made of molecules that act like magnets, you might suppose that the material would always be magnetized. But you know that this is not true. Usually, the material is not a magnet. We can explain this by the way in which the molecules are arranged. Look at the upper picture on this page. It shows what the arrangement of the molecules would be if we could see them. Notice that the tiny magnets are pointing in all directions. N poles and S poles of different molecules are facing each other. This fits the facts, because we know that unlike poles attract each other.

When the molecules are arranged like this, the material is not magnetized. There are just as many N poles as S poles in the molecules of the material. So the N poles and the S poles neutralize, or balance, the force of each other. This is like what

Unmagnetized material



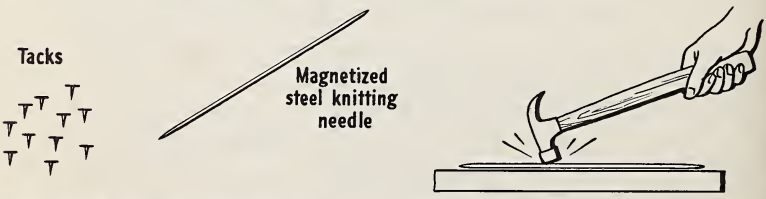
Magnetized material

happens when two boys pull on opposite ends of a rope. If just one boy pulls, the rope moves. But when both boys pull with equal force, nothing happens because the forces balance each other. In a material that is not magnetized, the poles of the tiny magnets neutralize each other. So the material is not a magnet.

We can also explain what happens when the material is magnetized. Lines of force from a magnet pass through the material, and they move the molecules into a new arrangement. The lower picture on page 251 shows what this arrangement would be. Notice that all the N poles of the tiny magnets point in one direction and all the S poles in the other direction. When the molecules are arranged like this, they no longer neutralize each other. So the material becomes a magnet. If you look at the picture carefully, you can see why one end of the magnet is an N pole and the other end an S pole. You can also see why the force of a magnet is strongest at its poles.

The theory of magnetism explains what happens when a material is magnetized. If it is a useful theory, it should also explain other facts about magnetism. Suppose that you pounded a magnet. What do you think would happen to its force? Experiment 12 will help you find the answer to this question.

Experiment **12** What happens when a magnet is pounded?



1 How many tacks will your magnet pick up?

2 Pound the magnet vigorously.

3 How many tacks will your magnet pick up now?

4 What has pounding done to the magnet? Is its force stronger or weaker?

5 What does this experiment show you about taking care of permanent magnets?

By using the theory of magnetism, we can explain what happens. When a magnet is pounded, the molecules are shaken up. Some of them are jarred out of their arrangement in a line. They turn so that their poles neutralize each other, and the magnet becomes weaker. In Unit 5, you learned what happens to the molecules of a material when it is heated. So you should be able to predict what will happen when a magnet is heated. Will its force become stronger or weaker? You can find out whether your prediction is correct by doing Experiment 13.

Experiment **13** What happens when a magnet is heated?

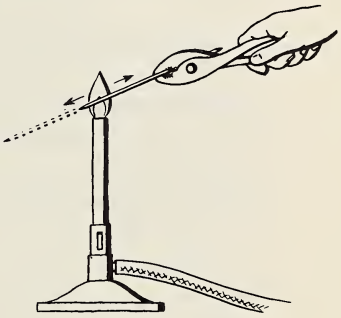
1 How many tacks will your magnet pick up?

2 Heat the magnet red-hot. Be sure to heat it all over. To do this, move the magnet back and forth through the flame. Then let it cool.

3 How many tacks will your magnet pick up now?

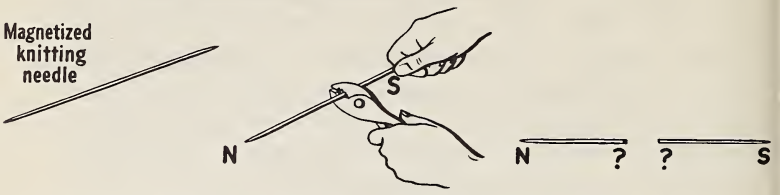
4 What has heating done to the magnet? Is its force stronger or weaker?

5 What does this experiment show you about taking care of permanent magnets?



When a material is heated, its molecules move faster. They bump into each other more often and knock each other farther apart. As the material expands, the molecules can move about more freely. When a magnet is heated, some of the molecules move out of line and turn so that they neutralize each other. So the magnet becomes weaker. The theory of magnetism also explains a fact that puzzled people for a long time. What do you think will happen if you cut a magnet in two? Experiment 14, on the next page, will help you find out.

Experiment 14 What happens when a magnet is cut in two?



1 How can you find out which is the N pole and which is the S pole of your magnet? Mark the N pole in some way.

2 Using a pair of pliers, cut or break the magnet in two.

3 Test the ends of the two pieces as you did before. What has happened where you cut the magnet?

4 What does this experiment show you about magnets?

When a magnet is cut in two, each piece becomes a magnet. The N pole of one piece is still where it was before, but the other end of this piece is now an S pole. The S pole of the other piece is still where it was before, but the other end of this piece is now an N pole. Where the cut was made, unlike poles are found on each side. If you stretch a string across the lower picture on page 251, you can see what happens.

The theory of magnetism is another example of a scientific theory. It does not tell us what magnetism is or how it is caused. But it does explain all the facts that are known about magnetism. So scientists accept it as a useful theory.

SELF-TESTING EXERCISES

1 According to the theory of magnetism, how are magnetic materials different from non-magnetic materials?

2 Explain why a magnetic material is not always a magnet.

3 How is a magnetized material different from one that is not magnetized?

4 Using the theory of magnetism, explain the facts that you observed in the last three experiments.

PROBLEMS TO SOLVE

1 Can you make a magnet that has only one pole? Explain your answer.

2 Why should you be careful not to drop a magnet?

3 Iron is used to make temporary magnets, while steel is used to make permanent magnets. How does the theory of magnetism explain these facts?

4 A magnet was left near a stove. When the magnet was tested some time later, it had lost some of its force. Why do you think this happened?

5 When an iron nail is held near one pole of a magnet, the nail becomes a temporary magnet. How does the nail become magnetized?

6 Pounding usually weakens a magnet. But if you hold a steel rod in a north-and-south direction and pound it vigorously, you can magnetize the rod. How can both these facts be true?

7 **a** A magnetized steel ring has no poles. How is this possible?
b If the ring is broken in two, will the pieces have poles? Why?

8 When bar magnets are stored, they are placed together with unlike poles touching each other. Explain why this is done.

The bottom of this little key box is a strong alnico magnet. Where might this be used? How do other things in this picture make use of magnets?

Magnets are now used to help geologists find minerals and oil in the earth. A magnetic instrument is hung from an airplane. As the plane flies back and forth across the country, the instrument records changes in the earth's magnetic field. From these changes, geologists can tell where minerals and oil may be.

SUMMARY EXERCISES

1 Make a list of the big ideas that you learned in this unit. Write them as complete sentences.

2 Show that you understand what the following words mean: magnetic material, non-magnetic material, alloy, poles of a magnet, magnetic field, lines of force, permanent magnet, temporary magnet, electromagnet, compass, N pole, S pole, dipping needle, geographic poles, magnetic poles.

ADDITIONAL ACTIVITIES

1 Show that nickel is a magnetic material. Get a large brass safety pin that is heavily nickel-plated. Tie a thread about two feet long to the middle of one side of the pin. Hang the pin up so that its ends can swing freely. After the pin stops swinging, bring the poles of a strong magnet near it. What happens? Explain.

2 Plan an experiment using a compass to find out which of two magnets is the stronger. Then do the experiment and explain your results.

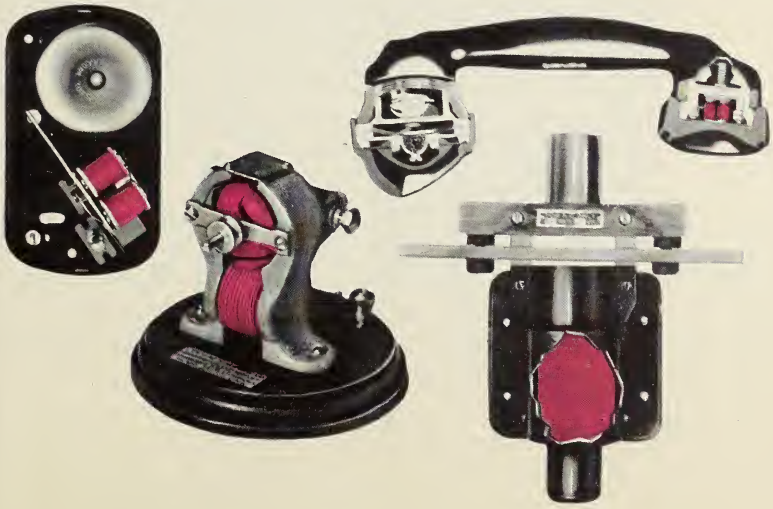
3 A piece of iron or steel attracts a magnet just as truly as the magnet attracts the iron or steel. Plan and do an experiment to show that this is true.

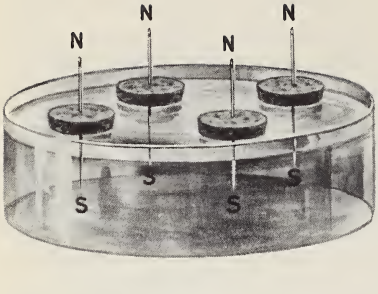
4 Make a nail float in the air. Hang a magnet from the top of a wooden frame. Tie a short thread around the head of a nail. Fasten the thread to a tack driven in the lower part of the frame. The thread should be just long enough to let the point of the nail reach within one-eighth inch of the magnet. Hold the point of the nail near the magnet and then let go of it. What happens? Why?

5 Use iron filings and a sheet of paper to find out how the field of force is arranged around a U-magnet or a horseshoe magnet when its keeper is about an inch from the poles. Try the experiment again but use a piece of aluminum, copper, or brass instead of the keeper. Then find out how the field of force is arranged when the N pole of one bar magnet is about an inch from the S pole of another bar magnet. Repeat the experiment but have two N poles or two S poles facing each other.

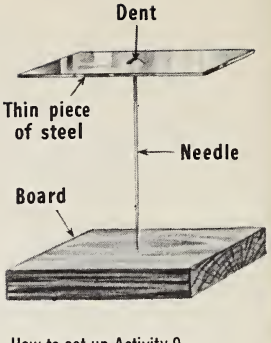
6 If you can get some blueprint paper, make blueprints of the different fields of force in Activity 5 above. You will need a dark room for most of the work. After the iron filings have arranged themselves, hold the blueprint paper in bright sunlight for about a minute. Go back into the dark room and pour off the iron filings. Soak the paper in cold water for several minutes and then lay it on a flat surface to dry. You should get a clear blue-and-white picture of each magnetic field.

Each device in these pictures has a part that is moved by an electromagnet. Find the electromagnets, which are colored red.





Part b of Activity 8



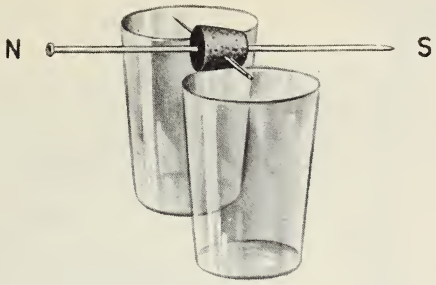
How to set up Activity 9

7 To do this experiment, you need two bar magnets that are just alike. Hold the bar magnets together with like poles touching each other and see how many tacks the magnets will pick up. Then repeat the experiment but have unlike poles touching each other. How many tacks are picked up this time? Explain.

8 **a** Magnetize four medium-sized needles. Be sure that the points are all N poles or all S poles. Put a sheet of cardboard over a bar magnet on a table and lay the needles on the cardboard over one pole of the magnet. Tap the cardboard lightly. Why do the needles act as they do? Repeat the experiment with the needles over the other pole of the magnet. Why do they act differently over this pole?

b Cut four thin, round slices from a large cork. Stick a magnetized needle halfway through each slice of cork. Put all the corks close together in a china or glass dish of water with the eyes of all the needles facing up. Let the water and the corks become still. What happens to the corks? Why? Repeat the experiment but turn the corks over so that the points of all the needles face up. What happens this time? Why? Do the experiment again but have two points up and two eyes up. What happens now? Explain.

9 Make a simple compass. Use a piece of broken hacksaw blade or old clock spring and a needle stuck in a thin board. Find where the piece of blade or spring balances in the middle and make a dent there with a hammer and nail. Magnetize the piece of blade or spring as strongly as you can. Then set the dent on the upper end of the needle stuck in the board.



How to make a dipping needle

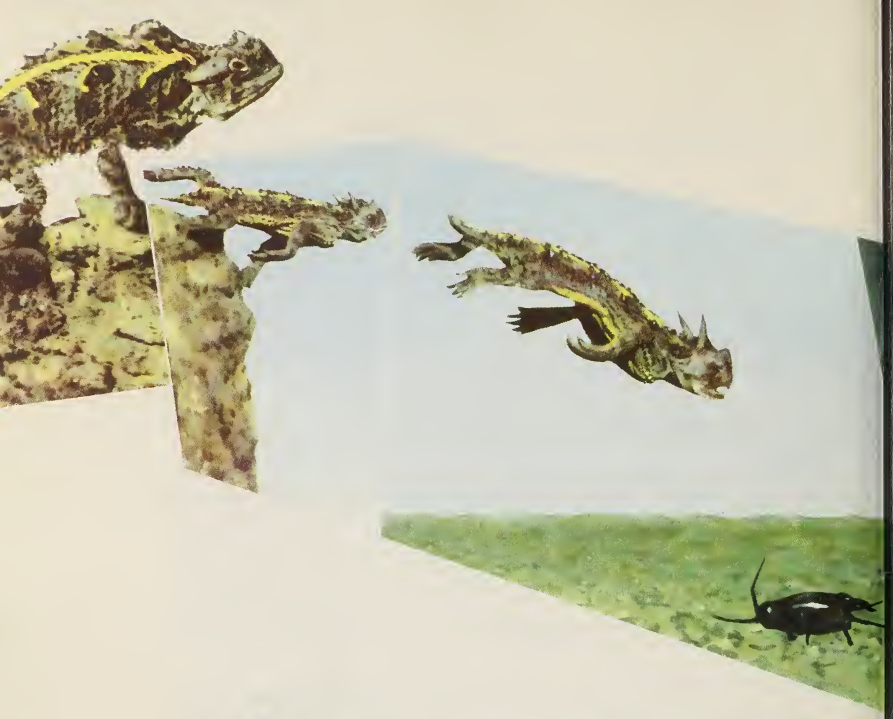
10 Make a dipping needle. Use a steel knitting needle and a large darning needle balanced on two glasses or jars. Push the knitting needle through a large cork. Then push the darning needle crosswise through the same cork. Set the ends of the darning needle on the glasses or jars. Adjust the needle in the cork until it stands level. Now magnetize the knitting needle strongly. When you set the darning needle back on the glasses or jars, does the knitting needle still stand level?

11 Make a magnet float in the air. You need two small, strong bar magnets made of alnico or cobalt-chrome steel. Drive two long staples into a board about two inches apart. Slip one magnet between the prongs of the staples. Then slip the other magnet through the staples so that like poles are together. What happens to the magnet on top? Why?

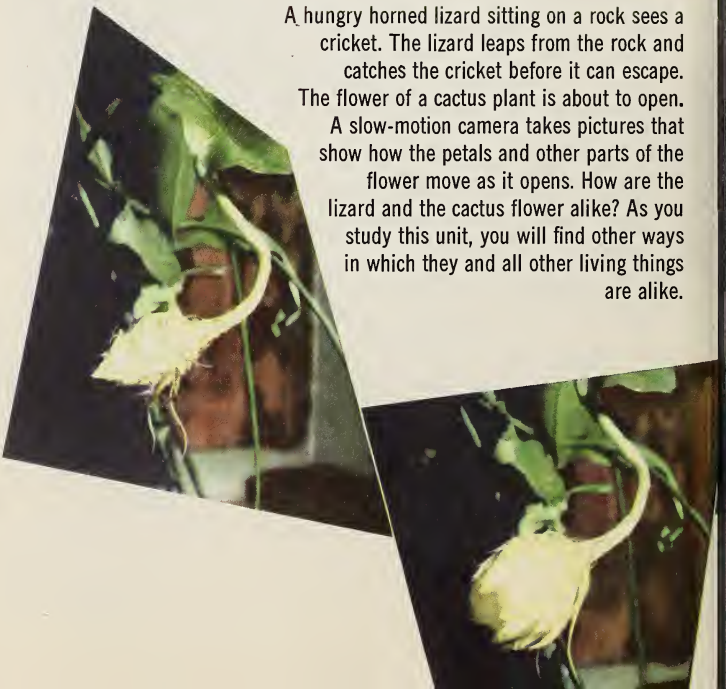
12 When people work around electrical machines, the steel parts of their watches sometimes become magnetized. Talk with a watch repairman to find out what effect this has on a watch. Also find out how a watch is demagnetized.

13 Magazines sometimes have pictures and articles about magnets and their uses. Make a collection of these pictures and articles.

14 In reference books, read about the following topics: Sir William Gilbert's discoveries about magnetism; uses of magnets; electromagnets; compasses; magnetite; the earth's magnetism.



A hungry horned lizard sitting on a rock sees a cricket. The lizard leaps from the rock and catches the cricket before it can escape. The flower of a cactus plant is about to open. A slow-motion camera takes pictures that show how the petals and other parts of the flower move as it opens. How are the lizard and the cactus flower alike? As you study this unit, you will find other ways in which they and all other living things are alike.



How are all living things alike?

UNIT 8

LOOKING AHEAD TO UNIT 8

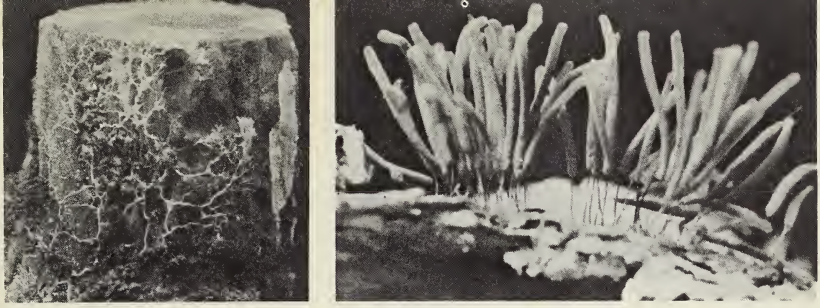
In Unit 2 you learned that more than a million kinds of living things have been discovered and named. Biologists classify living things by putting together in a group the ones whose bodies are alike in some way. Each group of living things has its own characteristics of structure, and no other group has exactly the same characteristics. All animals are put in one big group and all plants in another big group. Then each big group is divided into smaller groups with different characteristics of structure.

When a biologist classifies any living thing, he must first decide whether it is an animal or a plant. Perhaps you think that he can always tell plants from animals as easily as you can tell an oak tree from a squirrel. However, some strange kinds of living things have been discovered. Even an expert biologist sometimes finds it hard to decide whether these living things are animals or plants.

Suppose you are walking through the woods on a warm, moist day. You might see a white, jellylike mass sticking to the side of a dead tree. (See the picture on page 263.) Just by looking at it, you probably could not tell whether it is an animal or a plant. But if you marked its position with a pin and then came back several hours later, you might find that this mass had moved a little way up the tree. So you would probably think that it was an animal.

However, if you came back several days later when the weather was dry, you would surely be surprised. The jellylike mass that you thought was an animal would have disappeared. In its place you would find a dry, flat mass with featherlike parts that looks like a plant. This strange kind of living thing is called a slime mold. During the early part of its life, it is like an animal. Then in the later part of its life, it is like a plant. Is a slime mold a plant or an animal? Biologists have a hard time deciding, but most of them think that it is a plant. Whichever it is, biologists are sure that a slime mold is some kind of living thing.

All the things in our world are either living things or non-living things. A living thing is alive now or once was alive. Animals and plants are living things. Other things, such as air, water, and rock, are non-living things. A non-living thing is not alive now and



On the left is a slime mold crawling over a log. On the right the mold has formed the tiny, plumelike parts that carry the spores.

never was alive. But what does being alive really mean? If you can answer this question, you can tell three important ways in which a squirrel and an oak tree are alike. You can also explain how you are like a squirrel and an oak tree in the same three ways.

In your study of Unit 2, you learned that each kind of living thing is different in some way from all other kinds of living things. Now you are going to find out how all living things are alike. When you discover how animals and plants are alike, you will know something about what it means to be alive. You will also know how animals and plants are different from air, water, rock, and other things that never were alive. As you study this unit, you will find answers to such questions as these: What can all living things do? What are all living things made of? What materials are in all living things? How are living things different from non-living things?

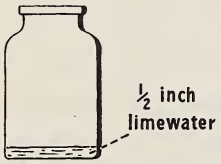
1 What can all living things do?

WHAT CAN ALL ANIMALS DO? Think of any animals that you know—cats, dogs, birds, snakes, frogs, fish, butterflies, spiders, crabs, snails, worms. What is one thing that all these animals can do? Probably the first thing you think of is that they can all move in some way. They can walk, crawl, fly, or swim. You may know some animals such as oysters, sponges, and corals that do not move from place to place. However, they can all move some parts of their bodies. That is one thing that all animals can do.

Animals have many different ways of moving. This porpoise can leap high out of the water to take the fish from the man's hand.

Perhaps you thought of another thing that all animals can do. All animals breathe. Some animals take air into their bodies with lungs. Others have gills. Still others take air directly into their bodies through their outer coverings. You know that air is a mixture of nitrogen, oxygen, carbon dioxide, and other gases. To find out what part of the air animals use, scientists tested the air that animals breathe in and out. The tests showed that the air which goes into an animal's body contains more oxygen than the air that comes out. The tests also showed that more carbon dioxide comes out than goes in. So scientists discovered that animals use oxygen and give out carbon dioxide. If you do Experiment 1, you can find out whether carbon dioxide is given out in your breath.

Experiment 1 Is carbon dioxide given out in your breath?



1 For what material is limewater a test? What happens when limewater is mixed with this material?

2 Shake the bottle. What happens to the limewater? What does this show?

3 Breathe into the bottle from the bottom of your lungs. Again shake the bottle. What happens this time? What does this show?

4 Why did you first shake the bottle with ordinary air in it?

There are other things that all animals can do besides move and breathe. All animals use food. You have probably watched many animals eat, and you may have seen others eat without your knowing that they were eating. Not all animals take in food as cats and dogs do. In Unit 2 you learned about the tiny animals called protozoans. One kind of protozoan, known as an amoeba (ə mē′ bə), takes in food with its whole body.

You know that animals grow until they are about the same size as their parents. Some animals grow faster than others. Houseflies become full grown in about eleven days. Dogs are not full grown until they are about a year old. Fish and some other animals keep on growing all their lives. Besides growing, there is another thing that all animals can do. They can all produce young animals. Some kinds of animals give birth to living young, but most kinds lay eggs. Most protozoans simply divide in two.

All animals can do one more thing. They can act when messages come to them from their surroundings. When animals see, a light message comes to their eyes from each thing that they see. Odors tell them when enemies, friends, or food are near. Sounds also give them messages. Biologists have a special word for a message like this. The word is *stimulus* (stim′ū ləs). Messages, such

What stimulus do you think the cat received? What stimulus is making the crayfish act as it is?

The leaf responds quickly by snapping its two halves together, trapping the ant between them.

An ant crawls onto the leaf of a Venus's-flytrap.

as light, sound, and odor, are different kinds of *stimuli* (stim′ū lī). The way in which an animal acts when it receives a stimulus is called a *response*. Most animals respond to stimuli from their enemies by running away, hiding, or fighting. When animals are hungry, they respond to stimuli from food by moving toward it and eating it. All animals respond to stimuli in some way.

SELF-TESTING EXERCISES

1 State six things that all animals can do.
2 **a** What material in the air do animals use?
  b What other material goes back into the air?
3 **a** Explain what is meant by a stimulus and a response.
  b Give at least two examples of animals responding to different stimuli.

WHAT CAN ALL PLANTS DO? You have learned six things that all animals can do. Now let us find out whether plants can do the same things. Do plants move? Certainly, plants cannot run or jump about. Yet scientists know that all plants can move. Because plants move much more slowly than most animals, we usually do

not notice that plants move. However, slow-motion pictures show plants sprouting from seeds or moving their stems, leaves, and petals. Look at the flower pictures on pages 260-261. If you could have watched this flower open, you would have seen the petals move. If you mark where the tip of a vine is and then come back several hours later, you may find that the tip has moved a little bit.

Do plants breathe? They surely do not have lungs or gills. Nor do they make any breathing movements that we can see. But careful tests show that plants take in oxygen. Because plants are not so active as animals, they do not need so much oxygen. Still, they must have oxygen to stay alive. When fields of wheat or corn are covered by a flood for several days, the plants die or are badly injured. Water keeps the air away from the leaves and roots, and the plants cannot get oxygen. To find out whether a plant gives out carbon dioxide, do Experiment 2.

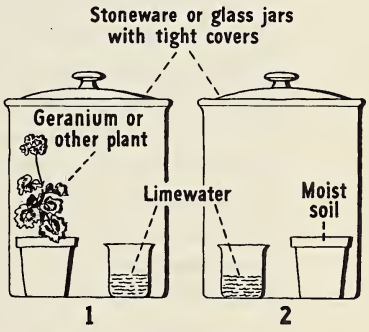
Experiment 2 Does a plant give out carbon dioxide?

1 What do you need to do this experiment?

2 How are Jar 1 and Jar 2 alike? How are they different? Why must the experiment be done in this way?

3 Let the jars stand overnight. (If the jars and covers are made of glass, keep them in a dark place.)

4 What happens to the limewater in Jar 1? In Jar 2? What does this show?



You cannot see a plant eat. Yet scientists know that plants use food. To stay alive, every living thing must have food. Plants that contain the green coloring matter called chlorophyll can make their own food. Plants without chlorophyll must get their food from other plants or from animals.

It took a year for an acorn to grow into this tiny oak tree.

Of course, you know that plants can grow. Seeds of flowers and vegetables planted in the spring become full-grown plants in just a few months. Where the climate is very hot, bamboo plants may grow as much as one foot in a day. Trees are the largest plants, and the giant sequoias of California have grown until they are the largest living things on the earth. Some scientists believe that these trees may be the biggest living things that ever existed.

Plants can also produce young plants. An oak tree makes acorns that can grow into more oak trees. A dandelion has hundreds of seeds that float through the air and start new dandelions growing. Ferns, mosses, and the larger algae and fungi produce millions of spores that can grow into new plants. The smaller algae and fungi make new plants by dividing in two. A yeast plant pushes out a little swelling called a bud. The bud is a young yeast plant that grows until it is as big as the first one. Then the bud breaks off and grows by itself.

So far, we have found that plants can do the same things that animals can do. Do you think that plants can also respond to stimuli? Just touching or shaking some plants will make their leaves fold together and droop. You may have noticed how the tip of a

This giant oak tree is probably several hundred years old. It grew from a tiny plant like the one on page 268.

young sunflower plant turns toward the sun. Or you may have seen the leaves of a geranium plant on a window sill turn toward the light. Perhaps you have noticed how the flowers of a four-o'clock close after dark. The stems and leaves of plants respond to the stimuli of the sun's light and heat by growing upward. The roots of plants respond to the stimulus of gravity by growing downward.

Now you have learned that plants can do the same six things that animals can do. Both plants and animals can (1) move, (2) breathe, (3) use food, (4) grow, (5) produce young, and (6) respond to stimuli. So you have discovered one important way in which all living things are alike: They can all do certain things. Perhaps being alive means being able to do all these things.

SELF-TESTING EXERCISES

1 State six things that all plants can do.

2 What is one important way in which all living things are alike?

3 **a** Name a gas that is given out by both animals and plants.

b What liquid is used to test for this gas?

c How does the liquid change when the gas is mixed with it?

PROBLEMS TO SOLVE

1 **a** How are a squirrel and an oak tree different? Mention as many differences as you can.
b How are a squirrel and an oak tree alike?

2 Name the kind of stimulus that makes you aware of these facts:
a Cabbage is being cooked. **b** You are eating sugar. **c** There is someone in the next room. **d** The sun is shining.

3 Both animals and plants respond to stimuli such as light, heat, and moisture. Do you think that animals or plants make more different kinds of responses? Why?

4 **a** Choose one kind of stimulus such as light or heat. Then tell what responses an animal might make to this stimulus.
b What responses might a plant make to the same stimulus?

5 **a** A fungus is growing on the side of a dead tree. Do you think that the fungus needs food to stay alive? Why?
b Where could the fungus get food?

2 What are all living things made of?

WHAT ARE CELLS? You have learned one important way in which all living things are alike: They can all do certain things. Most animals and plants are also alike in another way: They are made up of parts. A dog has a heart, lungs, stomach, eyes, ears, nose, and many other parts. A bean plant has a stem, roots, leaves, flowers, and pods with seeds in them. We call the main parts of an animal or plant its *organs*. Each organ does certain work for the animal or plant.

For a long time, people did not know what made up the organs of living things. But after the microscope was invented, scientists could examine small sections of the organs of animals and plants. Imagine the surprise of Robert Hooke, an English scientist, when about 300 years ago he looked at a piece of cork through a microscope like the one on page 26. He saw that the cork was made of tiny, hollow spaces with walls around them. These little spaces looked like the cells in a prison or in a honeycomb. So Hooke said that the cork was made of cells. You probably know that

cork was once part of a living thing. It is really the bark of a kind of oak tree.

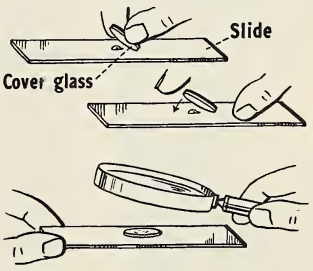
As time went on, other scientists saw cells in more and more living things. But they did not see cells in things that had never been alive. Then a little over 100 years ago, two German scientists, Matthias Schleiden (shlī'dən) and Theodor Schwann (shvän) had a great idea. After they had carefully studied many living things, they said that they thought all animals and plants are made of cells. Today, we know that these scientists were right. You, a squirrel, an oak tree, and all other living things are made of cells. If you make Observation 1, you can see some cells.

Observation 1 What do cells look like?

What you need: Sharp, single-edged safety-razor blade; cork, tomato, apple, potato, celery stalk, and maple twig; tweezers; medicine dropper; water; six glass microscope slides; six microscope cover glasses; magnifying glass (simple microscope); compound microscope.

What you do: With the safety-razor blade, make the thinnest shavings from freshly cut pieces of the plant materials. (Cut the celery stalk crosswise.) As you make each shaving, pick it up with the tweezers and put it in a drop of water on a separate glass slide. Lay a cover glass on the shaving to keep it moist and flat.

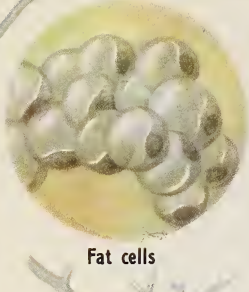
Now carefully lift up the glass slide so that the light shines through it and look at the plant shaving with the magnifying glass. If you can see what seem like tiny holes, you are looking



at spaces that contain (or did contain) plant cells. With the magnifying glass, you may also be able to find these spaces in the cut edges of thicker pieces of plant materials.

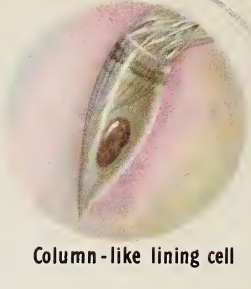
If a compound microscope is available, use it to examine each of the shavings. You should be able to see the spaces where the cells are (or were) much more clearly.

There are many different sizes of cells. The smallest cells that scientists have seen are one-celled plants called bacteria. Some bacteria are so tiny that they can be seen only through the most powerful microscopes. The one-celled animal called an amoeba is really a much larger cell. Even so, it would take about 100 large amoebas side by side to make a line an inch long. The yolk, or yellow part, of an ostrich egg is also just one cell. Yet it weighs about a pound.

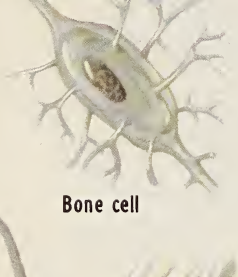


Fat cells

Scale-like covering cells



Column-like lining cell



Bone cell

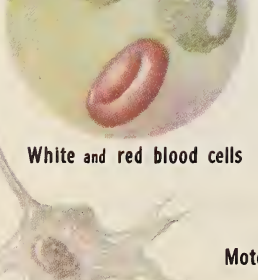
Animal cells

Some of the nerve cells in your body have long, slender branches that reach all the way from the lower part of your backbone to your toes. Think how long the nerve cells of an elephant or a giraffe must be! However, most cells of animals are quite small. They are usually even smaller than the cells of plants.

Cells make up the body of a living thing much as bricks or stones make up the walls of a building. But unlike bricks and stones, most cells are alive and doing things. The cells in your heart, muscles, and brain are beating, moving, and thinking. And the cells in an oak tree become larger and make new cells as the tree grows from an acorn. Everything that animals or plants can do is done by their cells.

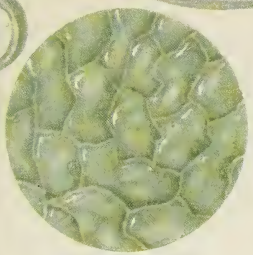
In one-celled animals and plants, just one cell does all the things that the animal or plant can do. However, in larger animals and plants, different kinds of cells do certain things and nothing else. Nerve cells of animals carry messages. Muscle cells help move parts of the body. Rounded cells hold stored fat. Flat, thin cells form a covering on the body. Even bones have cells in them. A hard material forms around the

Muscle cell

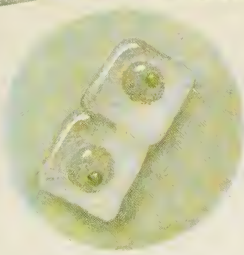


White and red blood cells

Motor nerve cell



Leaf-covering cells



Root-tip cells

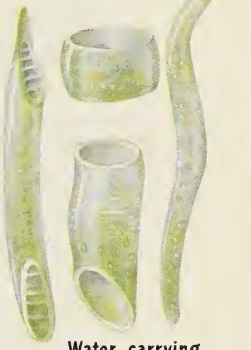
Stone cells

Plant cells

cells and makes the bones stiff, but the cells go on living inside the bones. When a bone is growing or if it is broken and needs repairing, the bone cells make new cells.

Plants, like animals, have different kinds of cells. Flat, thin cells form a covering on the leaves. Oblong cells in the leaves contain chlorophyll. Long, slender cells and short, thick cells make up the tubes that carry water and other materials from the roots through the stem to the leaves. Cells with thick walls help support the stem. A tree has very strong, thick-walled cells in its stem, or trunk.

All the cells in an animal or plant work together. Each different organ or part of an organ has its own kinds of cells. Each kind of cell is made in its own way and does certain work. It must depend on other kinds of cells to do the work that it cannot do. So the body of an animal or plant is like a community of people. The cells all work together, and each kind of cell does some special work for all the other kinds. If one kind of cell is hurt or dies, the whole community of cells may be disturbed and may even die.



Water-carrying cells

Food-carrying cells

Branching hair cells

Flax fiber cell

A community of one million billion (1,000,000,000,000,000) people, all working together, is hard to imagine. Yet you are a community of that many cells. Your brain alone has about two thousand billion cells in it, and your blood contains about fifteen thousand billion cells. Most of the time, your cells all work together very well.

SELF-TESTING EXERCISES

1 **a** What are the main parts of animals and plants called?
b Give at least three examples of these parts in animals and also in plants.
2 **a** How were cells discovered?
b Tell what cells are and what they can do.
3 How are the cells of amoebas and bacteria different from the cells of larger animals and plants?
4 Name three different kinds of animal cells and three different kinds of plant cells.
5 State three ways in which the body of an animal or plant is like a community of people.

WHAT ARE CELLS MADE OF? When Robert Hooke looked at a piece of cork through a microscope, he really saw only the walls of the cells. Many kinds of cells make walls around themselves. You learned that most of the cells in a tree trunk have very strong, thick walls. They make wood so stiff and hard that we can use it for buildings and furniture. However, many other kinds of cells, especially in animals, have no cell walls. So scientists know that a cell is not just a hollow space with a wall around it.

Inside all living cells there is a clear material somewhat like the white of an egg. We call this material *protoplasm* (prō′ tə plazm). Inside almost all cells there is also a rounded, heavier piece of protoplasm. This is called the *nucleus* (nū′ kli əs). Without its nucleus, a cell cannot live long. Practically all living cells have these two kinds of protoplasm: the lighter protoplasm in most of the cell and the heavier protoplasm in the nucleus. If you make Observation 2, you can see the important parts of cells.

Observation 2 What are the important parts of cells?

What you need: Knife; onion; tweezers; medicine dropper; water; two glass microscope slides; two microscope cover glasses; compound microscope; toothpick.

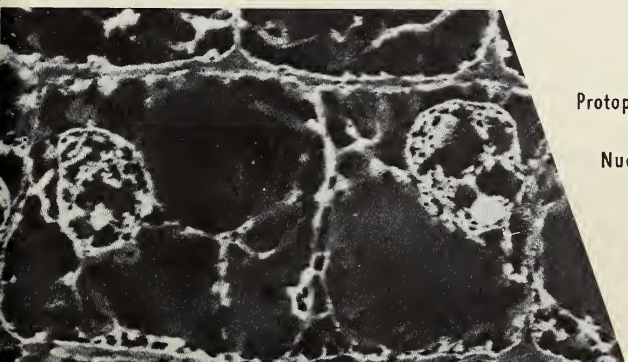
What you do: Cut a slice from the onion. Select one of the thick, juicy, inner layers. With the tweezers, peel off a piece of the inner or outer skin of this layer. This skin is very thin, and it should come off in an even sheet. Put the piece of onion skin in a drop of water on a glass slide and lay a cover glass over it.

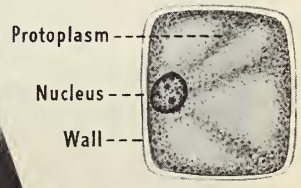
Examine the onion skin with the compound microscope. You should be able to see the cells and the cell walls clearly. Look for a tiny, round, yellowish lump inside each cell. This is the nucleus of the cell. Also look for the clear protoplasm around the nuclei or in little streaks near the cell walls or across the cells. It is not easy to see because most of the space inside an onion cell is filled with watery sap. To see the protoplasm more clearly, cut down the light coming into the microscope.

Gently scrape the inside of your cheek or lip with a toothpick. Then with the knife, scrape some of the white material on the toothpick into a drop of water on a glass slide. Spread the material out in the water and lay a cover glass over it. Examine the material with the compound microscope. You should be able to see some of the cells that line your mouth. The round spot in each cell is the nucleus.

A famous scientist once said that a cell is just a bit of protoplasm with a nucleus in it. Of course, a cell may have other parts, such as a cell wall. Yet the living active part of every cell is the protoplasm. Scientists can make some of the materials in protoplasm, but no scientist has ever been able to put the right things together in the right way to make protoplasm. So far as scientists know, only protoplasm itself can make more protoplasm.

On the left is a photograph of a cell from the root tip of an onion. With the help of the diagram on the right, find the different parts of the cell.





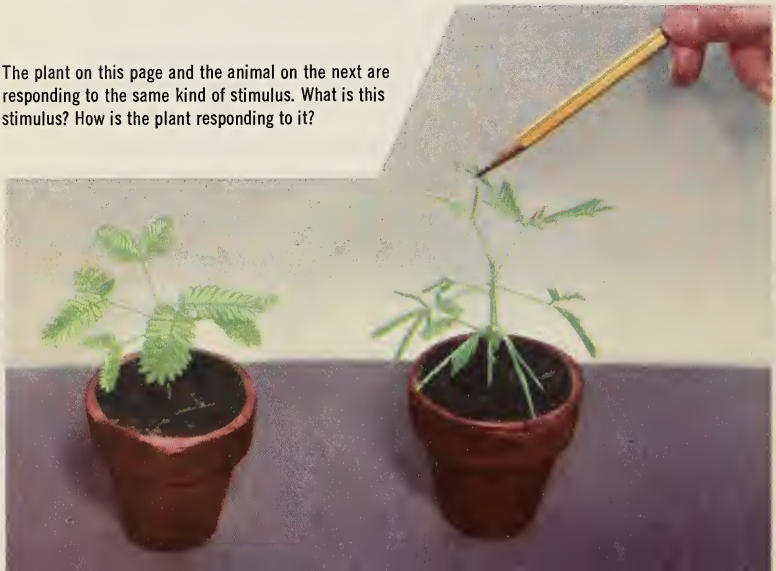
You know one way in which all living things are alike: They can all do certain things. They move. They take in oxygen and give out carbon dioxide. They use food. They grow. They produce young. And they respond to stimuli. You also know that all living things are made of cells. Everything that animals or plants can do is done by their cells. The living, active part of every cell is the protoplasm. So protoplasm really does all the things that animals and plants can do.

Protoplasm moves. It takes in oxygen and gives out carbon dioxide. It uses food. From food it makes all the materials that living things must have to stay alive. Some of these materials are used to make more protoplasm. Then living things can grow and repair worn-out or injured parts. Protoplasm produces new animals or plants. Protoplasm also responds to stimuli. Now you have learned another way in which all living things are alike: They are all made of cells that contain protoplasm. That is why all living things are alike in what they can do.

SELF-TESTING EXERCISES

1 What is protoplasm and what can it do?
2 What is the nucleus of a cell?
3 What can protoplasm do that scientists cannot do?
4 Explain why all living things are alike in what they can do.

The plant on this page and the animal on the next are responding to the same kind of stimulus. What is this stimulus? How is the plant responding to it?



How is the lizard responding to the stimulus? Why can the plant and the animal respond to the same kind of stimulus?

PROBLEMS TO SOLVE

1 What things can amoebas and bacteria do? How do you know?
2 Why does a large animal or plant need different kinds of cells?
3 Do you think that chemical changes are going on in your body? Give reasons for your answer.
4 Tell how a muscle cell and a nerve cell in your body might depend on each other. Give as many different ways as you can.
5 How do you know that the cells in your skin can make more cells like themselves?
6 Why do you suppose biologists are sure that a slime mold is a living thing?

What materials are in all living things? 3

WHAT ELEMENTS DO ANIMALS AND PLANTS CONTAIN? In Unit 5 you learned that everything in our world is made of elements. So you know that all living things must be made of elements. You also learned that two or more elements can combine to form a compound. The protoplasm in all living cells is a mixture of compounds. Chemists have worked out tests to find out what elements and compounds are in the body of an animal or plant. They also have ways to find out how much of each element and compound there is in the body.

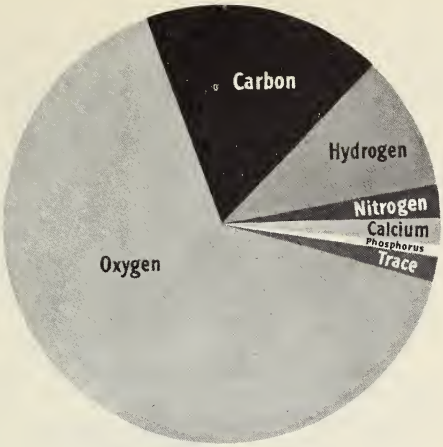
You have already put iodine on food to test for starch, and you have used limewater to test your breath for carbon dioxide. When a chemist makes tests like these, he is making a *chemical analysis* of a material. A chemical analysis shows what elements and compounds a material contains. It also shows how much of each element and compound there is in the material. When a chemist *analyzes* water, he finds that it is made of the elements hydrogen and oxygen. He also finds that it contains twice as many atoms of hydrogen as of oxygen. The formula for water (H_2O) shows both of these facts.

Now let us see what chemists have learned about the elements in a person's body. The picture on page 147 shows some facts about the elements in the body of a man. A more complete list of the elements in a person's body is given in the table on this page. The table also shows about how much of each element there is in the body of a person who weighs 100 pounds. Study the table carefully.

Elements in the body of a 100-pound person

Element	Pounds	Element	Pounds
Oxygen	65.0	Magnesium	0.05
Carbon	18.0	Iron	0.004
Hydrogen	10.0	Manganese	Trace
Nitrogen	3.0	Iodine	Trace
Calcium	2.0	Copper	Trace
Phosphorus	1.1	Cobalt	Trace
Potassium	0.35	Fluorine	Trace
Sulphur	0.25	Silicon	Trace
Sodium	0.15	Zinc	Trace
Chlorine	0.15	Aluminum	Trace

Notice that the first six elements in the table make up almost the whole body. In fact, most of the body is made up of the first four elements: oxygen, carbon, hydrogen, and nitrogen. Protoplasm contains all four of these elements. They take part in nearly all the chemical changes in living things. The next two elements,

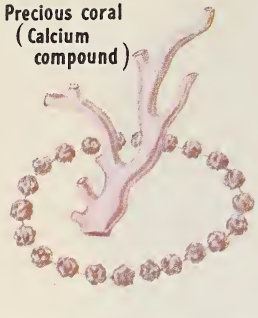


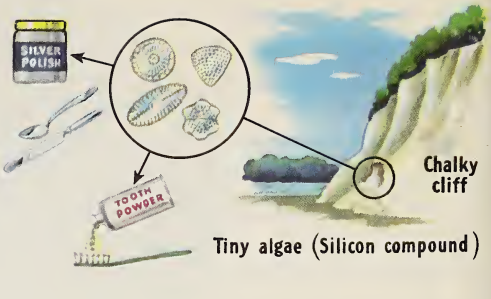
Study this circle graph. Which elements make up most of your body?

calcium and phosphorus, are mostly in the bones and teeth. The rest of the elements in the table do not seem to be very important. All of them put together do not make much more than a pound. There is so little of some of them that the weight is not given. Yet if any one of these elements is missing, a person probably cannot stay alive.

The bodies of most animals contain very nearly the same elements as the body of a person. However, some animals have more of certain elements in their bodies. For example, some sponges have much silicon in them. When chemists analyze plants, they find the same elements that are found in animals. They also find that plants, like animals, are mostly made up of oxygen, carbon, hydrogen, and nitrogen. Of these four elements, carbon is probably the most interesting for scientists to study. In all living things, carbon is the second element in amount. Nearly one fifth of your body is made of carbon.

There is a simple test for carbon that we often make accidentally. If a material turns black, or scorches, when it is heated, it probably has much carbon in it. Think how many times you have shown that there is carbon in toast, potatoes, meat, or even some of your clothes! Practically all of your food and clothing comes from animals and plants. So the carbon in your food and clothing must come from animals and plants, too.





Here are a few ways in which we use large amounts of certain elements and compounds that some plants and animals have in their bodies. Try to think of others.

SELF-TESTING EXERCISES

1 State two things that a chemical analysis shows about a material.
2 Name the four elements that make up most of the body of a living thing.
3 What two elements are found mostly in bones and teeth?
4 How can you make a simple test for carbon?
5 Where does the carbon in food and clothing come from?

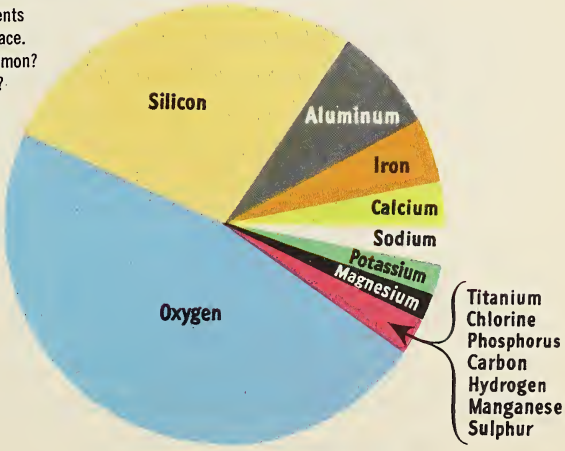
WHAT COMPOUNDS ARE IMPORTANT IN ANIMALS AND PLANTS? Suppose a chemist could get together all the elements that he would need to make a person weighing 100 pounds. The separate elements would fill a room 14 feet long, 14 feet wide, and 14 feet high. How can this much material go into the body of one person? You know that oxygen, hydrogen, nitrogen, and some of the other elements are gases. When they are gases, they fill up a great deal of space. But when they combine with other elements, they can form compounds that are liquids or solids. These compounds take up much less space.

One of the commonest compounds makes up about two thirds of the weight of animals and plants. This compound is water (H_2O). Water makes blood liquid. It forms most of the perspira-

tion, and it carries away wastes from the body. Our bodies and those of animals contain a small amount of salt (NaCl). You may have noticed the salty taste of sweat and blood. If some of the liquid from your stomach has ever come up into your mouth, you have noticed that it tastes sour. The sour taste is the taste of hydrochloric acid (HCl). This compound of hydrogen and chlorine helps digest food. The hard material in bones and teeth is mainly a compound called calcium phosphate. Its formula is $Ca_3(PO_4)_2$. So you can see that it contains calcium, phosphorus, and oxygen. Water, salt, and calcium phosphate are all common compounds. They are found in many places on or in the earth.

The bodies of animals and plants contain many other compounds made only by living things. You have learned that carbon is the second element in amount in animals and plants. The carbon in living things is all in compounds. Carbon forms about ten times as many different compounds as all the other elements that scientists have discovered. One of the simplest compounds of carbon is carbon dioxide (CO_2). You know that this compound of carbon is given out by animals and plants. Carbon dioxide is also used to make all of the thousands of different carbon compounds in living things. These carbon compounds give animals and plants the thousands of different colors, tastes, and odors that they have. All living things can make and use compounds of carbon.

This circle graph shows the elements that are found on the earth's surface. Which elements are the most common? Which ones are the least common?



You have now learned a third important way in which all living things are alike: They are all made of the same materials. Oxygen, carbon, hydrogen, and nitrogen are the commonest elements in both animals and plants. Protoplasm contains all four of these elements. Water, a compound of hydrogen and oxygen, makes up about two thirds of the weight of animals and plants. Thousands of different carbon compounds are made and used by living things.

SELF-TESTING EXERCISES

1 **a** Tell where in your body you could find each of these compounds: salt, calcium phosphate, hydrochloric acid.
b Name the elements in each of the compounds.
2 **a** What compound given out by living things is used to make many different compounds?
b Name the elements in this compound.
3 **a** What compound makes up most of the weight of living things?
b Name the elements in this compound.
4 How are all living things alike in the materials they are made of? Give as many different ways as you can.

PROBLEMS TO SOLVE

1 Find out how much you weigh. Then refer to the table on page 278 and figure out how many pounds of each of the six commonest elements there are in your body.
2 **a** What do we call the chemical change that takes place when oxygen combines with another element?
b Do you think that this chemical change takes place in all living things? Give reasons for your answer.
3 If you did not get enough calcium in your food, what parts of your body would be harmed most? Explain your answer.
4 Why do you think that all living things need air and water?
5 Look at the circle graph on page 281. Compare it with the one on page 279. Are all the elements in the earth's surface also in a person's body? What differences do you find? What elements that are common in a person's body are not common in the earth's surface?

4 How are living things different from non-living things?

In this unit you have learned three important ways in which all living things are alike: (1) They can all do certain things. (2) They are all made of cells that contain protoplasm. (3) They are all made of the same materials. Now let us find out how living things are different from non-living things.

If you think carefully, you will discover that some non-living things can do some of the things that animals and plants can do. You know that an automobile or a locomotive can move. However, it cannot move by itself. Some outside force must make it move. Non-living things do not use food, but automobiles and locomotives use fuel. To burn the fuel, they take in oxygen. They also give out carbon dioxide. Non-living things do not produce young. Yet some of them can grow even though they are not alive. In Unit 3 you learned about solutions. When water evaporates from a solution, crystals of the dissolved solid are sometimes left. These crystals are little sharp-cornered pieces, and they can grow. To see how a crystal grows, make Observation 3.

Observation 3 How do crystals grow?

What you need: One-half pound of powdered alum, copper sulphate, or sodium thiosulphate (hypo); crystal of the same compound; two drinking glasses (or beakers); warm water; spoon (or stirring rod); two sheets of paper; thread; short stick (or stiff wire).

What you do: Add the powder to a glass of warm water and stir until no more powder will dissolve. Be sure to add enough powder so that some is left undissolved in the bottom of the glass. Cover the glass with a sheet of paper to keep out the dust. Let the solution stand for at least twenty-four hours.

Then pour most of the clear solution into a clean glass. Tie a crystal of the compound on one end of a thread. Fasten the other end of the thread to a stick. Lay the stick across the top of the glass so that the crystal hangs down into the solution. Cover the glass loosely with a sheet of paper and set it where it will not be disturbed for several days.

Watch the crystal to see whether its size or shape changes. Usually it will grow. How does it grow? How is the way in which a crystal grows different from the way in which a living thing grows?

Look carefully at the picture and find the crystal in the center. This is called the seed crystal. Do you see that the seed crystal has grown bigger? Has it grown in the same way in which a plant seed grows? Explain your answer.

A crystal becomes larger by adding more layers of the same material on the outside of itself. This is quite different from the way in which a living thing grows. A squirrel eats acorns and then changes them into bone, muscles, skin, and fur. This change takes place inside the body of the squirrel. When any living thing grows, its food must first be changed into living material. Then the new living material is added to the body from the inside. All living things grow from the inside.

You surely know that some non-living things can respond to stimuli. An automobile or a locomotive responds to a stimulus when someone pushes or pulls a lever. So you can see that some non-living things can do one or more of the things that animals and plants can do. However, no non-living thing can do all the things that living things can do.

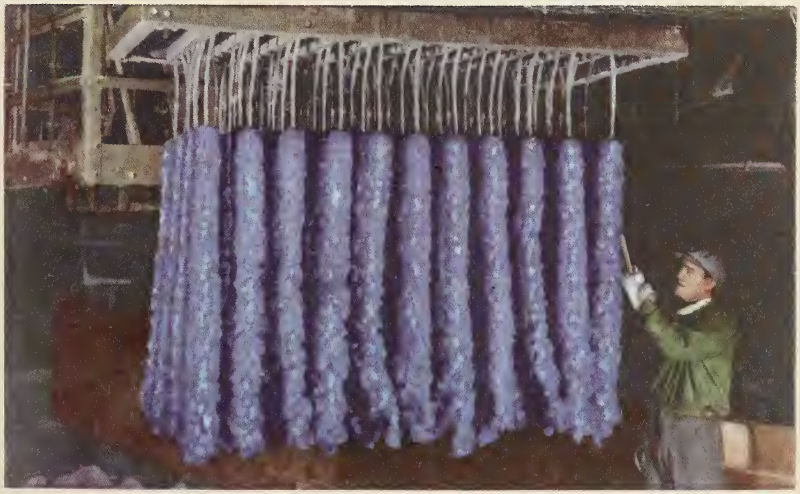
No scientist has ever found cells in a thing that was never alive. So non-living things do not contain protoplasm. Non-living things are made from elements just as living things are. Yet the element carbon makes living things very different from non-living things. Almost one fifth of every living thing is carbon. But less than one fiftieth of the air and one five-hundredth of the rock on the outside of the earth is carbon. So for its size, a living thing contains about ten times as much carbon as air and about a hundred times as much carbon as rock. Non-living things like coal and petroleum are mostly carbon. But both coal and petroleum were made from living things that existed long ago.

You remember that biologists have a hard time deciding whether some living things, such as slime molds, are plants or animals. Biologists are also puzzled about whether some things are alive or not. You have probably heard or read about viruses that cause diseases such as colds, measles, influenza, smallpox, sleeping sickness, infantile paralysis, and rabies. Viruses are much smaller than the tiniest bacteria. Until the electron microscope was invented, no one had ever seen a virus. Viruses can grow only on living things, but they seem to grow more like crystals. Scientists still are not sure whether viruses are living or non-living things.

SELF-TESTING EXERCISES

1 How are living and non-living things alike? Give as many ways as you can.
2 State three important ways in which living things are different from non-living things.
3 How is the growth of a living thing different from the growth of a crystal?

Copper-sulphate crystals are grown on long rods of copper that hang down into a solution of copper sulphate.



PROBLEMS TO SOLVE

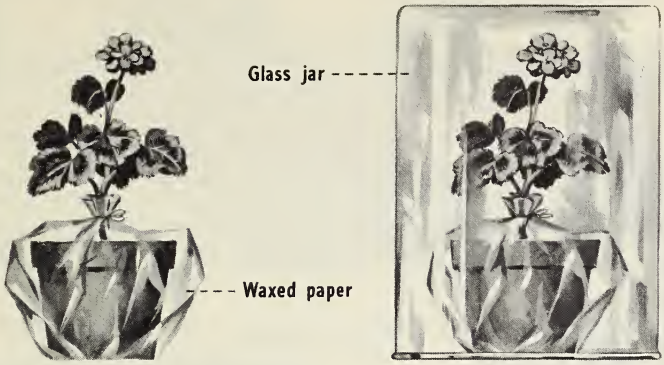
1 **a** How are a horse and a locomotive alike?
b How are they different?
2 A furnace or stove takes in oxygen and gives out carbon dioxide. Why can a furnace or stove not be called a living thing?
3 How do you think scientists know that coal and petroleum were made from living things?
4 Suppose you found some small icicle-shaped things hanging from the roof of a cave. When you came back a year later, these things were a little larger. They seemed to be alive because they had grown. How could you find out whether they were really living things? Explain your answer.
5 Make a list of non-living things that respond to stimuli. Be sure to tell what each stimulus is.

SUMMARY EXERCISES

1 Make a list of the big ideas that you learned in this unit. Be sure to write them as complete sentences.
2 Show that you understand what the following words mean: living, non-living, stimulus, response, organ, cell, protoplasm, nucleus, chemical analysis, virus.

ADDITIONAL ACTIVITIES

1 Work out a plan for observing the movements of plants or parts of plants. Then make your observations and report your findings to the class.
2 Plan and carry out an experiment to show that plants respond to the stimulus of light.
3 If you have a pet, such as a cat, dog, bird, or fish, observe it to discover the different kinds of stimuli to which it responds.
4 Plan and carry out an experiment to show that the roots of plants grow down and the stems grow up.
5 Put several fertile eggs under a setting hen or in an incubator kept at 103° F. Also put some bean seeds between pieces of moist blotting paper or towel paper. Keep the paper moist. After five days break an egg into a shallow dish of warm salt water. Then compare



How to get the plants ready for Activity 7

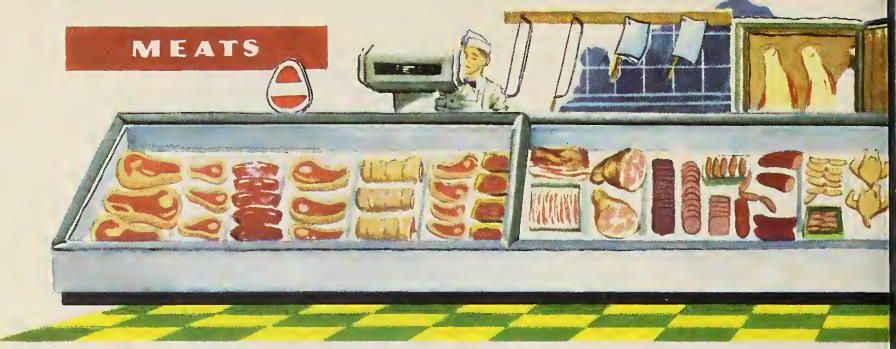
the egg with a bean seed. What has happened to each of them? How are the things that happened to them alike?

6 Find out how long it takes different animals and plants to become full grown. Then make a report to the class.

7 Get a potted plant and a large glass jar that will fit over it. Wrap the pot in waxed paper so that water cannot evaporate from the pot or the soil. Fasten the paper around the stem, leaving only the stem and leaves sticking out. Be sure that the glass jar is clean and dry. Then set it over the plant and leave it there for several hours. What do you find on the inside of the jar? Where did this come from?

8 Plan and do an experiment to find out how much water there is in an apple, potato, or the like.

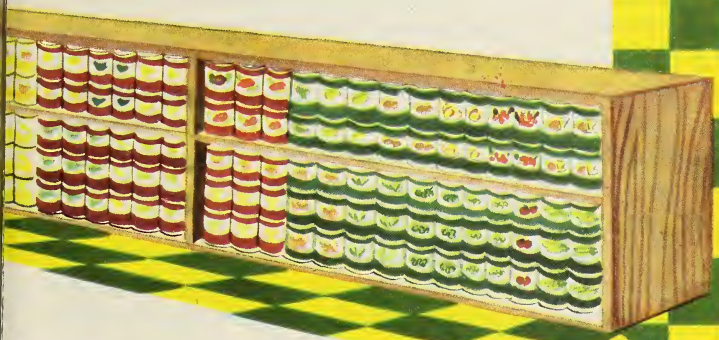
9 In reference books, read about the following topics: Robert Hooke's discovery of cells; protoplasm; slime molds; viruses.



When you go into a big market like this one, you must go to different parts of the store for different kinds of food. This arrangement is not only convenient for the storekeeper, but it also helps people buy the things they need. What groups of foods do you see? What kinds of things do you find in each group? Look at the food that the woman has bought. What groups did she choose from? Why do you think she chose as she did? As you study Unit 9, you will be able to answer this question more fully.

Why do you eat different kinds of food?

UNIT 9



LOOKING AHEAD TO UNIT 9

Like every other living thing, you must have food to stay alive. The feeling of hunger is the signal that lets you know when your body needs food. After you have eaten, you feel satisfied. Even if you do not eat the foods that your body needs, you no longer are hungry. A meal of cake, pie, cookies, candy, and "pop" makes you feel just as satisfied as a meal of meat, potatoes, vegetables, bread and butter, fruit, and milk. Hunger lets you know when to eat, but it does not tell you what to eat.

Long ago, people seldom had much choice of foods. They usually ate whatever foods they found near their homes. Today, you can eat foods that come from many parts of our own country and also from other countries. Though you have a much larger choice than ever before, perhaps you would rather eat only the foods that you like best. But your parents have a good reason for urging you to eat other foods. To get the materials that your body needs, you must eat different kinds of food.

Scientists have analyzed hundreds of different foods, and they have discovered what materials each food contains. They have also learned which of these materials and how much of them your body needs. Scientists know that food must supply your body with at least forty different elements and compounds. Unless your body gets all these materials, it cannot work properly. If you choose your foods carefully, your body will get the materials that it needs. But your body must have these materials regularly. That is why you should form the habit of eating enough of the proper foods every day.

Many people never form this important habit. Without spending any more money, they could improve their choice of foods. But some people think that choosing foods carefully is too much bother. They eat all that they want of whatever they like. Other people have heard so many different ideas about food that they do not know what they should eat. They may go without some foods entirely and not eat enough of others. Yet there is really no reason for being either lazy or confused about choosing foods. You can easily learn what to eat and how much to eat.

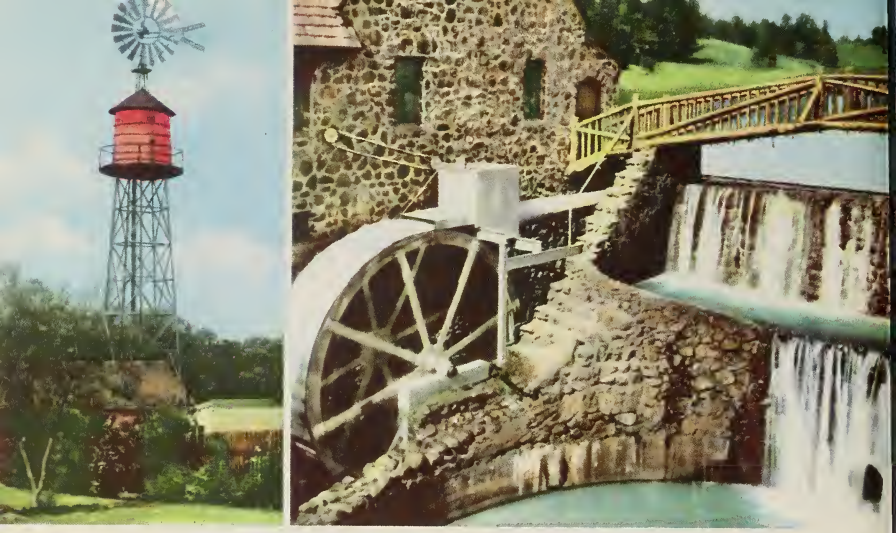
Many years ago people could not go to stores like the one on pages 288-289 to get their food. The whole family worked together to prepare it, and they ate only what they could get near home.

This unit provides some simple suggestions for forming good eating habits. As you study the unit, you will learn why you should follow these suggestions. You will also find answers to such questions as these: Why do you need food? What kinds of food do you need? How can you choose the foods that you need?

1 Why do you need food?

WHAT DOES FOOD DO FOR YOUR BODY? You and all other living things can move. In fact, moving is the most noticeable thing that you do. Your legs, arms, and head move. Your heart beats as it pumps blood around through your body. Your chest moves in and out as you breathe with your lungs. Different parts of your body are always moving. But nothing moves unless it has been pulled or pushed by a force. And without energy, there would be no force. Energy is what makes things happen. So you must have energy to produce the force that moves your body. Where does this energy come from?

Coal, gasoline, and other fuels all have energy stored in them. When a fuel is burned, the stored energy is set free. This energy can be used to make things move. A locomotive or an automobile



In each of the pictures on these pages, energy is making something move.

gets its energy from the fuel that is burned in the engine. You get your energy from the fuel that is burned in your body. The fuel that you use is food. Like other fuels, food contains stored energy. Food is fuel for your body just as coal or gasoline is fuel for an engine. When any fuel is burned, or oxidized, heat is always given off. Scientists know that heat is really a form of energy. When food is oxidized in your body, the heat energy that is given off keeps your body warm. So the energy to move your body and keep it warm comes from the food that you eat.

Food also supplies the materials that your body needs. From the materials in food, the protoplasm in your cells makes many different compounds. Some of these compounds are used to make more protoplasm. Your body grows as its cells become larger and new cells are formed. Parts of your body are being destroyed all the time. When you work or play hard, many of your muscle cells wear out. If you cut or burn yourself, some of your skin cells are injured. Your body makes new protoplasm and new cells to repair the worn-out or injured parts. Even broken bones can be mended. As your body grows and repairs itself, the food that you eat becomes part of you.

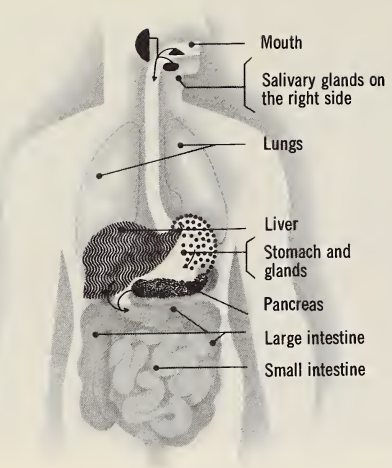
In each picture, what is moving and what is providing the energy to make it move?

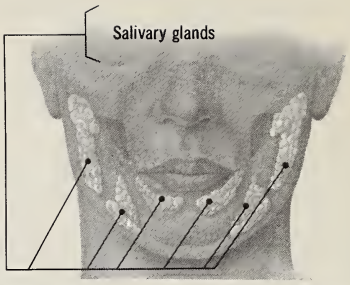
From the materials in food, protoplasm also makes many different chemicals. These chemicals are compounds that keep your body working properly. Some chemicals digest your food. Other chemicals regulate how fast your food is used, how fast you grow, how rapidly your heart beats, and how much your muscles contract. Your body is made up of about one million billion cells, all working together. To keep these cells working properly, your body must have the chemicals that protoplasm makes from food.

Now you have learned two important things that food does for your body: (1) Food provides the energy that your body needs to move and keep warm. (2) Food provides the materials that your body needs to grow, repair itself, and keep working properly. Anything that supplies either energy or materials used in your body is called a food.

SELF-TESTING EXERCISES

1 Explain why food is fuel for your body.
2 Why does your body need a supply of materials?
3 State two important things that food does for your body.
4 What do we mean by a food?





The picture on the left shows the digestive glands of the body. The arrows show where the juice from each gland is used. As you read page 295, look at this picture and follow the path of food through the body. From the picture above you can see that there are salivary glands on both sides of the face.

HOW DOES YOUR BODY USE FOOD? Every living cell in your body uses food. So there must be some way for food to get to each cell. Your blood carries food to all parts of your body. But only dissolved food can get into your blood and then into your cells. Before food can be used in your body, it must first be digested. When *digestion* takes place, the food that you eat is made into a solution.

From what you have learned about solutions, you know that water is the greatest solvent in the world. Water dissolves more kinds of materials than any other liquid. Yet there are many materials that water does not dissolve. The water that you drink dissolves some foods, but it does not dissolve all foods. Your body must change most of the food that you eat into other compounds that will dissolve. Digestion changes your food chemically and dissolves it. The chemicals that change food are made in your body. Organs called digestive glands give out chemicals mixed with water. These mixtures of chemicals and water are digestive juices. Different juices digest different kinds of food.

You can understand digestion better if you remember what you learned in Experiments 3 and 4 of Unit 3. You saw that sugar would dissolve in water but starch would not dissolve.

Many foods that you eat contain starch. Before this starch can be used by your body, it must be changed into a compound that will dissolve. The digestive juice called saliva is given out by glands connected with your mouth. Saliva contains a chemical that changes starch into sugar. The sugar made from the starch will dissolve. If you do Experiment 1, you can see how saliva helps digest starch.

Experiment 1 How does saliva help digest starch?

What you need: Teaspoon; starch; two glasses (or beakers); water; gas burner (or other source of heat); matches; pan; six test tubes; medicine dropper; dilute iodine solution; small piece of cloth (or cotton); funnel.

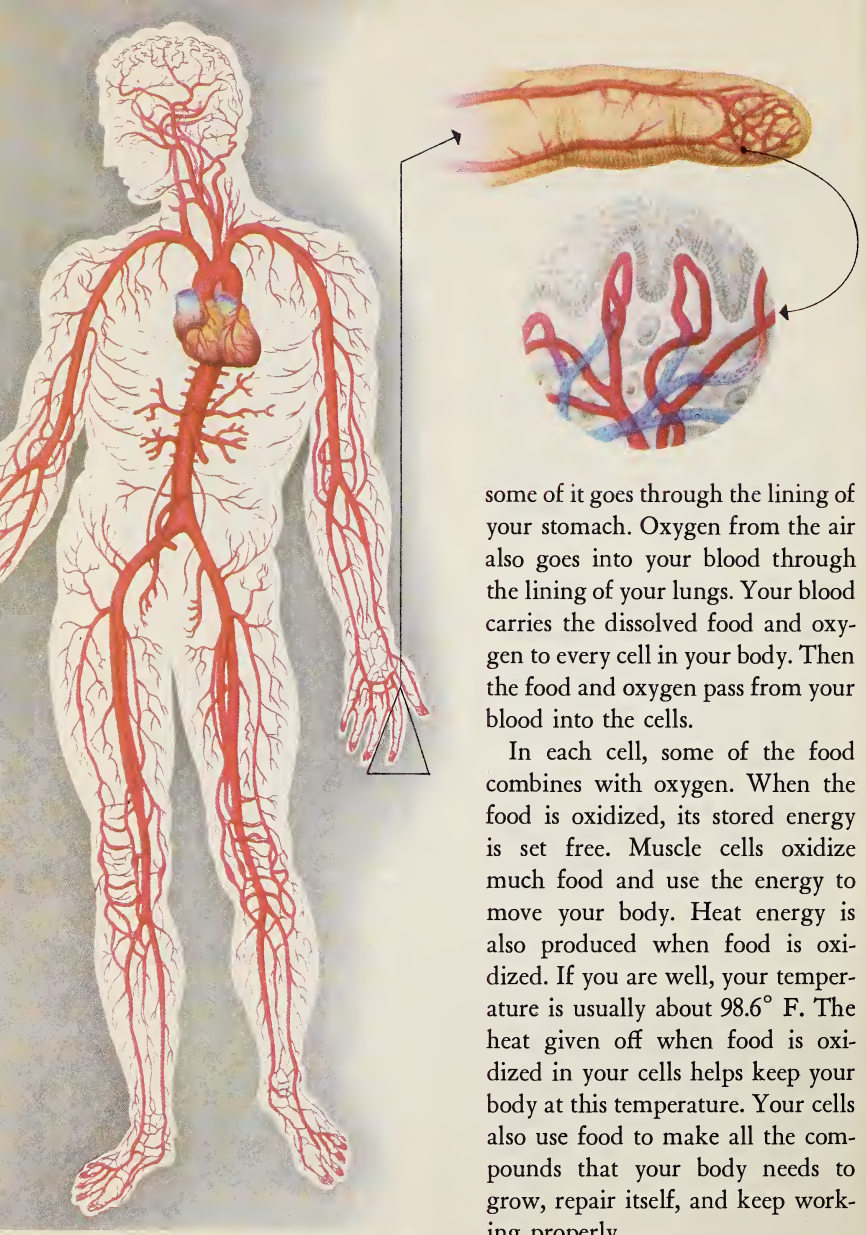
What you do; Put a teaspoonful of starch in a glass of cold water and stir the mixture thoroughly. Pour the mixture into a pan and heat to boiling. Then cool it by adding a glass of cold water. Has the starch dissolved? How do you know? Pour a little of the mixture into a test tube and add a drop of iodine solution. What happens? What does this show?

Now put a small piece of water-soaked cloth (or a thin layer of wet cotton) in the bottom of the funnel. Collect saliva in the funnel until the test tube is one-fourth full of clear saliva. Pour a little of the saliva into another test tube and add a drop of iodine solution. What happens this time? What does this show?

Fill the test tube that contains saliva with the starch mixture and mix the two liquids thoroughly. Stand the test tube in a glass of warm water to keep the mixture at the temperature of your body. Then compare the starch-saliva mixture with the starch mixture in another test tube. Does the starch seem to have dissolved in the saliva? Why do you think so?

Pour some of the starch-saliva mixture into another test tube and add a drop of iodine solution. What happens? What has become of the starch? (If there is any starch left in the mixture, put the mixture back in the glass of warm water. After the mixture has stood for a time, test it again.)

Digestion begins when you put food in your mouth. Here the food is chewed and mixed with saliva. Then the food moves down into your stomach and small intestine. They hold the food and mix it with other digestive juices until everything that can be digested is chemically changed and dissolved. The part of the food that is not digested is pushed along into the large intestine and then passed out of the body. Most of the dissolved food goes into your blood through the lining of your small intestine, but



A network of tubes carries blood from your heart to every part of your body. Follow the arrows to see how these tubes get smaller and smaller until they reach the cells in part of your finger tip.

some of it goes through the lining of your stomach. Oxygen from the air also goes into your blood through the lining of your lungs. Your blood carries the dissolved food and oxygen to every cell in your body. Then the food and oxygen pass from your blood into the cells.

In each cell, some of the food combines with oxygen. When the food is oxidized, its stored energy is set free. Muscle cells oxidize much food and use the energy to move your body. Heat energy is also produced when food is oxidized. If you are well, your temperature is usually about 98.6° F. The heat given off when food is oxidized in your cells helps keep your body at this temperature. Your cells also use food to make all the compounds that your body needs to grow, repair itself, and keep working properly.

SELF-TESTING EXERCISES

1 Where is food really used in your body? Explain your answer.
2 How does food get to all parts of your body?
3 Why must food be digested before your body can use it?
4 Explain what is meant by digestion.
5 Why does your body need different kinds of digestive juices?
6 In your own words, tell what happens to your food from the time when you eat it until it is used in your body.

PROBLEMS TO SOLVE

1 Why must your cells have oxygen to stay alive?
2 Do people who live in cold climates need more food or less food than people who live in hot climates? Give reasons for your answer.
3 You breathe out much more carbon dioxide than you breathe in. Where is this gas formed in your body? Explain your answer.
4 Explain why you breathe faster after running.
5 Does oxidation take place in your body all the time or only part of the time? How do you know?
6 A boy or a girl often uses as much food as a full-grown person. Why do you think this is true?
7 After working or playing hard, you feel much warmer. Explain.
8 How does your body use energy while you are asleep?
9 Why should you chew your food thoroughly before swallowing it?
10 Which man in the pictures below needs to eat more food? Why?

2 What kinds of food do you need?

WHAT KINDS OF FOOD PROVIDE YOU WITH ENERGY? When any fuel is oxidized, it produces energy. The energy that your body needs to move and keep warm comes from the fuel that you use. This fuel is food. Many foods that you eat can be oxidized in your body, but not all of them are good fuels. A good fuel must produce a large amount of energy. Yet it should not cost too much for the amount of energy produced. You know that paper, cloth, wood, and coal will all burn. But we do not use paper and cloth as fuels. They would cost too much for the amount of energy produced.

It is much the same with the foods that you eat. Some foods are better fuels than others. The best fuels for your body are the kinds of food known as carbohydrates and fats. So carbohydrates and fats are often called fuel foods. When fuel foods are oxidized in your body, they produce large amounts of energy. For this reason, carbohydrates and fats are also called energy foods. The table on page 306 gives the percentages of carbohydrates and fats in common foods.

Mountain climbers carry foods that do not weigh much yet supply energy quickly.

These foods contain large amounts of starch. Which ones do you usually eat every day?

Starch and sugar are carbohydrates. Much of the starch that you eat comes from grains such as wheat, corn, oats, rye, and rice. Breakfast cereals, bread, crackers, spaghetti, macaroni, and noodles are all foods made from grains. Potatoes, dried beans, and dried peas also contain much starch. You can easily tell which foods contain sugar, because they taste sweet. Candy, honey, corn syrup, molasses, fruits, and berries have much sugar in them. In Experiment 4 of Unit 5, you tested foods for starch. Now you can test foods for certain kinds of sugar by doing Experiment 2. However, you cannot test for cane or beet sugar with the solution that you will use.

Experiment 2 How can you test foods for sugar?

What you need: Test tubes; Fehling's solution; foods such as corn syrup, bread, fruits, etc.; test-tube holder; gas burner (or other source of heat); matches; water; small porcelain or glass dish.

What you do: Fill a test tube one-third full of Fehling's solution and pour in a very little corn syrup. Heat the liquid in the test tube. A red or yellow color shows that the food has sugar in it. Test other foods for sugar in the same way. Crush and soak solid foods, such as bread, in a little water in a dish. Then pour off some of the liquid and test it for sugar. Which foods have sugar in them? Which foods do not? Make a list of the foods in which you found sugar and another list of the foods in which you found no sugar.

We get almost all of our different kinds of sugar from plants. But we get fats from both plants and animals.

All greasy and oily foods contain fats. An oil is a fat that is liquid at ordinary temperatures. Cottonseed oil, corn oil, peanut oil, soybean oil, olive oil, coconut oil, and fish-liver oil are liquid fats. Butter, margarine, and lard are solid fats. Fat meat, egg yolk, nuts, cream, and cheese all contain large amounts of fats. You can test foods to find out whether they contain fats by doing Experiment 3.

Experiment **3** How can you test foods for fats?

What you need: Foods such as salad oil, butter, cheese, egg yolk, nuts, meats, etc.; shiny, white paper; gas burner (or other source of heat); matches.

What you do: Mash a small piece of the food on a sheet of shiny, white paper. Then warm the paper over a flame. BE CAREFUL NOT TO SET THE PAPER ON FIRE. Hold the paper up to the light and look for a grease spot. The grease-spot test shows only the foods that contain a rather large amount of fat. Which foods have much fat in them? Which foods do not? Make a list of the foods in which you found much fat and another list of those that had little or no fat.

Fats and carbohydrates are compounds made of the same three elements—carbon, hydrogen, and oxygen. But fats contain less oxygen than carbohydrates. So more oxygen can combine with fats when they are used as fuel in your body. For this reason, fats produce more energy than the same amount of carbohydrates. When your cells oxidize an ounce of fat, they get more than twice as much energy as when they oxidize an ounce of sugar. Fats are the most concentrated energy foods that you can eat. From fats and carbohydrates, you get most of the energy that your body needs to move and keep warm.

SELF-TESTING EXERCISES

1 Name two common carbohydrates and then give at least four examples of foods that contain each one.

2 Give at least six examples of foods that contain fats.

3 **a** Why are carbohydrates and fats called fuel foods?
b Why are they also known as energy foods?

4 **a** What elements are fats and carbohydrates made of?
b Which kind of food produces more energy when it is oxidized in your cells? Why?

WHAT KINDS OF FOOD PROVIDE YOU WITH MATERIALS? Your body needs other things besides the energy that it gets from fats and carbohydrates. It must also have materials to grow, repair itself, and keep working properly. The kinds of food that provide most of these materials are proteins, minerals, and water. The table on page 306 gives the percentages of proteins, minerals, and water in common foods.

Proteins are compounds that contain carbon, hydrogen, and oxygen, just as fats and carbohydrates do. But besides these three elements, all proteins contain one other element—nitrogen. Nitrogen makes up about one sixth of most proteins. Some proteins also contain sulphur and phosphorus. Most of the proteins that you eat come from lean meat, eggs, fish, milk, and cheese. Peas, beans, and soybeans also have large amounts of proteins in them. If you do Experiment 4, you can test foods for proteins.

Experiment 4 How can you test foods for proteins?

What you need: Foods such as meats, cheese, egg white, dried beans, etc.; test tubes; dilute nitric acid; test-tube holder; gas burner (or other source of heat); matches; ammonium hydroxide (or household ammonia).

What you do: Put a small piece of the food in a test tube. Add a few drops of nitric acid. BE CAREFUL NOT TO GET THE ACID ON YOURSELF OR YOUR CLOTHES. Heat the test tube gently. A yellow color shows that the food contains protein. Pour any extra nitric acid into a dish and put in at least an inch of ammonium hydroxide. The yellow color will turn darker or change to orange. Which foods have proteins in them? Which foods do not? Make a list of the foods in which you found proteins.

Sometimes you may not eat enough fuel foods to provide all the energy that your body needs. If this happens, your cells can oxidize proteins to get extra energy. Proteins will supply about as much energy as the same amount of carbohydrates. But for the energy produced, proteins usually cost more than carbohydrates or fats. So proteins are not used mainly as fuel. Your body has a much more important use for proteins.

Scientists know that protoplasm is made almost entirely of proteins and water. In Unit 8 you learned that protoplasm con-

tains oxygen, hydrogen, carbon, and nitrogen. Water is made of only two of these elements—hydrogen and oxygen. But proteins contain all four of them. To make new protoplasm, your cells must have proteins. Without proteins, your cells cannot grow or make new cells. Nor can they repair worn-out and injured parts of your body. Your cells cannot make proteins from fats and carbohydrates. They must get the materials from the proteins that you eat. Proteins provide your body with building materials, and so they are often called body-building foods.

Besides oxygen, hydrogen, carbon, and nitrogen, your body contains at least sixteen other elements. Beginning with calcium and phosphorus, they are the last sixteen elements in the table on page 278. As the table shows, a person's body contains only very tiny amounts of most of them. They all come from compounds known as minerals. So these elements are often called minerals, too. When a food is burned as completely as it can be, only the minerals are left. Probably you would call them ashes. But when chemists analyze food, they call these minerals ash. If you do Experiment 5, you can test foods for minerals.

Experiment **5** How can you test foods for minerals?

What you need: Foods such as meats, milk, cheese, green vegetables, etc.; iron pan (or spoon); gas burner (or other source of heat); matches.

What you do: Put a small piece of the food in the iron pan. Heat the pan as hot as possible. Keep it hot until all the food has burned and only white or gray materials are left. These are the minerals, or ash, in the food. Which foods have minerals in them? Which foods do not? Make a list of the foods in which you found minerals and another of those that left no minerals.

Your body needs fairly large amounts of calcium and phosphorus to make the hard material in your bones and teeth. Calcium also helps your blood thicken, or clot, if you cut yourself. New blood cells must have iron and copper to grow. Your hair and nails need sulphur. A chemical that controls the beating of your heart contains sodium. Chlorine is used to make hydrochloric acid, a digestive juice in your stomach. Without iodine,

These are the foods that supply your body with the most proteins.

the *thyroid* (thī′ roid) gland in the front of your neck cannot make its chemical. Lack of iodine may cause a disease called *goiter* (goi′ tər), in which the thyroid gland becomes much enlarged. Potassium, magnesium, manganese, cobalt, fluorine, and perhaps other mineral elements are needed in your body.

Minerals provide your body with building materials. In this way, they are body-building foods like proteins. However, minerals also supply materials to make chemicals that your body needs. Because these chemicals protect your body and keep it working properly, minerals are sometimes called protective foods. Most people get enough of all the mineral elements except four —calcium, phosphorus, iron, and iodine. Milk and cheese provide calcium and phosphorus, while egg yolk and meats provide phosphorus and iron. Some vegetables contain all three of these elements. Fish, oysters, clams, and other seafoods are unusually rich

in iodine. If you do not eat much seafood, you can use iodized salt, which has a very small amount of iodine in it.

Water from wells and springs often contains minerals, but water alone is an important material in your body. You know that about two thirds of your weight is water. Protoplasm is about four fifths water, and so is blood. Water helps digest food and carry on many other chemical changes in your body. It also helps keep your body at the proper temperature and removes waste materials. To stay alive, your body must have plenty of water. At least two quarts of water are lost from your body every day. Even if you drink four glasses of water a day, you cannot replace all the water that is lost. But food provides much of the water that you need. Milk, soup, and other liquid foods are mostly water. So are juicy fruits and vegetables, such as melons, apples, and tomatoes. The table on page 306 shows that many common foods contain much water.

SELF-TESTING EXERCISES

1 **a** Which element in all proteins is not in fats and carbohydrates?
  b What other elements do some proteins contain?
  c Give at least six examples of foods that contain proteins.
2 **a** When are proteins used to provide your body with energy?
  b What is the most important use of proteins in your body?

Your body gets minerals and water from foods like these. What else do you get from some of them?

Percentage composition of common foods

Food	Carbohydrates	Fats	Proteins	Minerals	Water
Apples	14.9	.4	.3	.3	84.1
Bacon, lean	1.1	53.0	12.2	4.7	29.0
Bananas	23.0	.2	1.2	.8	74.8
Beans, dried	62.1	1.5	22.0	3.9	10.5
Beans, green	7.7	.2	2.4	.8	88.9
Beef, round		13.0	19.1	.9	67.0
Butter (or margarine)	.4	81.0	.6	2.5	15.5
Bread, white enriched	49.8	3.6	9.0	1.6	36.0
Bread, whole-grain	47.0	4.0	10.0	2.0	37.0
Cabbage	5.3	.2	1.4	.7	92.4
Cake, plain frosted	62.1	6.2	5.2	1.3	25.2
Candy, chocolate bar	57.7	33.5	6.0	1.7	1.1
Carrots	9.3	.3	1.2	1.0	88.2
Cheese, cheddar	1.7	32.3	23.9	3.1	39.0
Cheese, cottage	4.3	.8	19.2	1.7	74.0
Chicken, roast		5.0	21.1	1.1	72.8
Corn, sweet	20.5	1.2	3.7	.7	73.9
Crackers, soda	72.7	9.6	9.6	2.4	5.7
Cream	4.0	20.0	2.9	.6	72.5
Dates	75.4	.6	2.2	1.8	20.0
Eggs, hen	.7	11.5	12.8	1.0	74.0
Ham, smoked	.7	25.0	19.5	5.8	49.0
Ice cream, vanilla	20.3	13.0	3.9	.8	62.0
Jellies	65.0		.2	.3	34.5
Lamb, leg		9.0	19.0	1.0	71.0
Lettuce	2.9	.2	1.2	.9	94.8
Liver, calves	4.0	4.9	19.0	1.3	70.8
Macaroni	19.4	.4	3.7	1.5	75.0
Milk, whole	4.9	3.9	3.5	.7	87.0
Oranges	11.2	.2	.9	.5	87.2
Oysters	5.9	2.0	9.8	2.0	80.3
Peanut butter	21.0	47.8	26.1	3.4	1.7
Peanuts	16.5	48.5	27.6	2.3	5.1
Peas, green	17.7	.4	6.7	.9	74.3
Perch		.8	18.7	1.2	79.3
Pork, loin		18.0	18.0	1.0	63.0
Potatoes, sweet	27.9	.7	1.8	1.1	68.5
Potatoes, white	19.1	.1	2.0	1.0	77.8
Raisins	71.2	.5	2.3	2.0	24.0
Salmon, canned		9.6	20.6	2.4	67.4
Tomatoes	4.3	.2	1.0	.5	94.0
Veal, leg		8.0	20.0	1.0	71.0

3 Explain what is meant by the minerals in food.

4 **a** Which mineral elements are most likely to be lacking in your food?

b What foods will provide these elements?

5 Why are proteins and minerals called body-building foods?

6 **a** Explain why your body must have plenty of water.

b Name several foods that help keep your body supplied with water.

WHY ARE VITAMINS IMPORTANT IN YOUR FOOD? To stay alive, your body must have both energy and materials. Fats and carbohydrates provide most of the energy, while proteins, minerals, and water provide most of the materials. But your body needs another kind of food besides the kinds that you have studied so far. You know that minerals are not only body-building foods. They are also protective foods, because they provide elements to make chemicals that your body must have to keep working properly. Vitamins are protective foods, too. The discovery of vitamins is one of the most interesting stories of science.

More than 400 years ago, the explorer Magellan set out to sail around the world. During the long voyage, his sailors' mouths became sore and their gums bled. Then their joints swelled until the men screamed with pain. The sailors had a disease called scurvy. When they reached the Philippine Islands, where there was fresh food to eat, they soon got well. For many years, scurvy was common on ships that made long voyages. Then doctors discovered that sailors did not get scurvy if they had lime juice, lemon juice, or orange juice to drink.

Another mysterious disease was causing much sickness in China, Japan, and other parts of the world. People who had the disease first noticed that their legs felt numb. Then the calves of their legs became painful. Finally, the people became paralyzed and died. They had a disease called beriberi. To prevent this disease, one doctor tried an experiment. He gave better food to people who might get the disease, and none of them got it. Other doctors discovered that certain foods, such as whole-wheat flour, would prevent beriberi.

The rats in these pictures are the same age. The rat in the top picture has rickets. In his diet he had none of the foods that prevent rickets. The rat in the lower picture had plenty of these foods. He grew properly and has strong, straight bones.

Throughout the world, but especially where people do not get much sunlight, many children have soft bones. When the children begin to walk, their bones will not support their weight. The bones become crooked, and the children may be crippled for life. They have a disease called rickets. Many people are handicapped because they had rickets at some time in their lives. While doctors were trying to find a cure for this disease, an important fact was discovered. Where people ate much codfish, there was no rickets. Cod-liver oil prevented the disease. Eskimos never had rickets. Most of their food was fat and oil from fish. Doctors also found that children who had rickets got well when they were exposed to the light from the sun or from sun lamps.

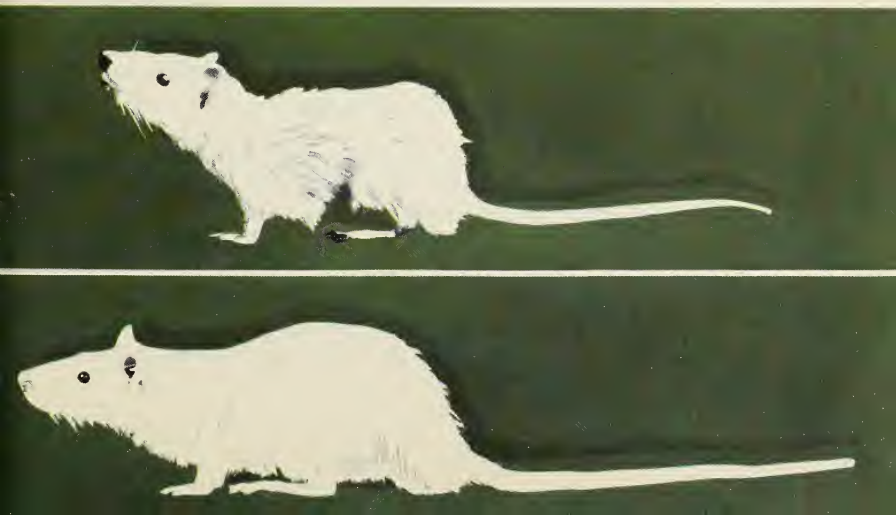
A strange disease, called *pellagra* (pə lā′grə or pə lag′rə), has long been common in many parts of our own country. In this disease, the hands, feet, and face break out. People who have pellagra become nervous and fearful, and they cannot sleep at night. They may even become insane and then die. For many years, no one knew what caused the disease. Then a doctor discovered that people who ate fresh meat and drank milk did not get pellagra. Later, he learned that yeast would cure the disease.

All the facts that scientists were discovering about these terrible diseases seemed to have only one explanation: Food must

do something more than provide the body with energy and building materials. To find out whether this explanation was correct, scientists did many experiments with food. They tried giving different foods to such animals as rats and guinea pigs. Before long, the scientists discovered that the animals could not live on just pure carbohydrates, fats, proteins, minerals, and water. One scientist found that only one-half teaspoonful of milk added to the other foods each day would keep a rat healthy. Then another scientist discovered that a little yeast powder added to the food would do the same thing as milk. What was in the milk and yeast that had this effect?

Scientists all over the world kept working on this problem. Finally, they showed that certain foods contain special chemicals which we must all have to keep well. These chemicals were named vitamins. At first, scientists did not know what the chemicals were. So they named the different vitamins with the letters of the alphabet—vitamins A, B, C, D, and so on. Now chemists know exactly what compounds most vitamins are. They can even make many of these compounds. The alphabet names are slowly going out of use. The names such as thiamin (thī′ə min), riboflavin (rī′bə flā′vin), niacin (nī′ə sin), and ascorbic (ə skôr′bik) acid are becoming more common. Scientists are

The rat in the top picture has lived on nothing but meat, potatoes, bread, and butter. He has not grown well, and his fur is in poor condition. The rat below had the same diet with milk and vegetables added. Why has he grown into a larger, healthier animal?



still trying to learn more about the vitamins already discovered, and they are searching for vitamins yet unknown.

The table on this page lists some of the important vitamins, together with their uses and sources. By studying the table, you can learn why your body must have each one of these vitamins. If a person does not get enough of some vitamin, he may develop

Important uses and sources of vitamins

Vitamin	Uses	Sources
Vitamin A	To promote growth and development To help resist infections To promote better night vision To keep the skin healthy	Fish-liver oils, liver, kidney, yellow vegetables, leafy, green vegetables, butter, cream, milk, cheese, eggs, dried apricots, tomatoes, potatoes
Vitamin B_1 (Thiamin)	To prevent nervousness To increase appetite To help digestion To help body use carbohydrates To prevent beriberi	Lean pork, liver, kidney, lean beef, whole-grain cereals, dried beans, green peas, potatoes, eggs, milk, nuts, fruits
Vitamin B_2 (Riboflavin)	To promote growth To keep skin and muscles healthy To help oxidize food	Liver, lean meat, milk, eggs, leafy, green vegetables, dried beans, lima beans, soybeans, whole-grain cereals, nuts
Niacin (Nicotinic acid)	To promote growth To keep the skin healthy To keep the stomach and intestines working properly To prevent pellagra	Whole-grain cereals, liver, lean meat, chicken, fish, peanuts, potatoes, peas, beans, eggs, milk
Vitamin C (Ascorbic acid)	To keep the walls of the blood vessels strong To keep the bones, teeth, and gums healthy To regulate the heart muscles To help resist infections To prevent scurvy	Citrus fruits, tomatoes, cabbage, green vegetables, potatoes, berries, melons
Vitamin D	To help the body make the best use of calcium and phosphorus in bones and teeth To prevent rickets	Fish-liver oils, sunlight, egg yolks, irradiated milk, butter, cream, salmon, sardines, herring
Vitamin K	To prevent excess bleeding and maintain normal clotting of blood	Leafy, green vegetables, egg yolks, soybeans, milk, milk products

a *deficiency* disease such as scurvy, beriberi, rickets, or pellagra. A deficiency disease is caused by the lack of some material in a person's food. The material is usually a vitamin or a mineral. Only small amounts of the material are ordinarily needed. To prevent rickets, your body needs each day a bit of vitamin D no bigger than the period at the end of this sentence.

Meat, eggs, whole-grain bread and cereals, milk, butter, and fresh fruits and vegetables provide your body with most of the vitamins that you need. However, you may not get enough vitamin D from your food. Vitamin D is made in some foods and also in your body by certain invisible rays from the sun. Scientists call them *ultraviolet* rays. In winter, people wear heavy clothes and stay indoors a great deal. Even when they are outdoors, clouds and smoke shut off much of the sunlight. So their bodies do not make enough vitamin D. You can make up for the lack of vitamin D by taking fish-liver oil or some other material that contains much of the vitamin. Or you can expose yourself to the ultraviolet rays from a sun lamp. But if you use a sun lamp, you should follow the advice of a doctor. Too much exposure to a sun lamp or to the sun itself is dangerous.

SELF-TESTING EXERCISES

1 Why are vitamins as well as minerals called protective foods?
2 **a** What is meant by a deficiency disease?
  b Name four deficiency diseases that can be prevented by vitamins.
3 What made scientists think that some diseases were caused by the lack of proper foods?
4 Why were vitamins at first named only with letters of the alphabet?
5 What foods will provide most of the vitamins that your body needs?
6 **a** Which vitamin may be lacking in your food?
  b State two ways in which you can make up for the lack of this vitamin.

PROBLEMS TO SOLVE

1 If you live in a very cold climate, are you likely to eat more carbohydrates or more fats? Explain your answer.
2 Why must you always have some proteins in your food?

People in some parts of the world eat much codfish that has been dried in the sun. These people seldom have rickets. How can you explain this?

3 Because water, minerals, and vitamins do not provide energy for the body, some people think that these materials should not be called foods. Do you agree? Give reasons for your answer.

4 **a** Find table salt in the list of compounds on page 151. What is its chemical name? What elements is it made of?

b Is salt an important mineral in your body? Explain your answer.

5 Do you think that goiter is a deficiency disease? Why?

6 **a** Why is fish-liver oil or something like it usually given during the winter to babies in the northern part of our country?

b Why do babies not need so much of this material in the summer?

7 Using the table on page 306, make a list of at least ten foods that you often eat. Then after each food in your list, write the word or words that show whether the food is a good source of carbohydrates, fats, proteins, or minerals.

8 **a** Refer to the table on page 310. Name the vitamin that prevents each deficiency disease mentioned in the table.

b List several foods that are good sources of each of these vitamins.

How can you choose the foods that you need?

3

WHAT FOODS SHOULD YOU EAT? You have learned why your body needs food and also what kinds of food it must have. Carbohydrates and fats provide most of the energy that your body uses, while proteins, minerals, vitamins, and water provide most of the materials. Your meals should contain all these different kinds of food, not just a few of them. In other words, your *diet* should be well balanced. Diet means the variety of foods that you usually eat.

What you have learned about foods will not do you much good unless you use it every day. So now you are going to find out how to choose the foods that you should eat. Scientists have worked out a plan that will give you a well-balanced diet. This plan is shown in the chart on page 313. In the chart, the foods that you should eat are put into seven groups called the basic seven. These groups are basic because each one supplies some of the different kinds of food that your body needs.

As you study the chart, you can see that the first three groups include many vegetables and fruits. These foods contain vitamins A and C, minerals such as iron, and much water. The green vegetables and the yellow vegetables in Group 1 are rich in vitamin A and iron. Some green vegetables also contain vitamin C, but the juicy fruits and vegetables in Group 2 are the best sources of this vitamin. Potatoes and other vegetables and fruits in Group 3 are good sources of vitamin C and minerals. White potatoes supply iron, and sweet potatoes are rich in vitamin A. Both kinds of potatoes contain large amounts of carbohydrates. These three basic groups of foods are important to the body in still another way. The parts of the foods that are not digested fill up the large intestine and help empty it regularly.

Group 4 is made up of milk and milk products such as cheese. Whole milk is a nearly complete food. Though it is mostly water, it contains carbohydrates, fats, and proteins. It is rich in calcium and phosphorus, which your body must have to make strong, healthy bones and teeth. A quart of milk every day will provide all the calcium and more than half the phosphorus that your body needs. Milk is an excellent source of vitamins A and B_2, and it is a good source of vitamin B_1. Much of the milk sold today also contains some vitamin D. The milk is exposed for a few minutes to ultraviolet rays from a sun lamp. Milk with vitamin D added in this way is called irradiated milk.

Meat, poultry, fish, and eggs are put into Group 5, together with peas, beans, nuts, and peanut butter. These foods contain large amounts of proteins, which your body must have to make more protoplasm. The foods in this group usually contain some fats. Most of the foods are good sources of the B vitamins and

You would have to eat 27 pounds of potatoes to get the same amount of minerals and vitamins that you get from a quart of milk. How much of other common foods would you need to eat?

iron. Peas, beans, and nuts also supply some calcium and phosphorus. But milk is by far the best source of these two important minerals.

Bread, flour, cereals, and other foods made from grains are in Group 6. These foods contain large amounts of carbohydrates, which your body uses for energy. They also contain some proteins. When the foods are made from whole wheat or another whole grain, they are good sources of the B vitamins and iron. However, most people do not like dark, coarse, whole-wheat bread. They prefer white bread made from flour that has lost most of its vitamins and minerals. To make up for part of this loss, flour or bread is now enriched by adding B vitamins and iron. Enriched bread is a better food than plain white bread, but it is still not so good as bread made from whole wheat. Cereals are said to be *restored* when they have been enriched with B vitamins and iron.

The last group of the basic seven includes butter and margarine. Butter is made from cream, which is the fat in milk. Margarine is ordinarily made from a vegetable oil, such as cottonseed oil or soybean oil. So both foods in this group are mostly fats. An ounce of margarine produces the same amount of energy as an ounce of butter. However, butter is an excellent source of vitamin A, which margarine lacks. Most of the margarine sold

today is *fortified* by adding this vitamin. When butter and margarine have been irradiated, they also contain some vitamin D.

Now you can understand why you should follow the basic-seven plan in choosing your foods. If you eat foods from each basic group every day, you will have a well-balanced diet. Eating the basic seven is much easier than trying to pick out foods that will provide your body with enough carbohydrates, fats, proteins, minerals, vitamins, and water.

SELF-TESTING EXERCISES

1 What is meant by a well-balanced diet?

2 Explain why you should eat several different vegetables and fruits every day. Give as many reasons as you can.

3 Why is milk considered one of our very best foods?

4 State three reasons for eating such foods as meat, poultry, fish, eggs, peas, beans, and nuts.

5 **a** What is the main reason for eating bread and other foods made from grains?

b Why is enriched bread a better food than plain white bread?

6 **a** How is butter different from margarine?

b How are these foods alike?

7 Why should you follow the basic-seven plan in choosing your foods?

8 Show how the meals in the pictures below include the basic seven.

HOW MUCH FOOD SHOULD YOU EAT? Eating food from each of the seven basic groups every day will give you a well-balanced diet, but you must also eat enough of these foods. Can you follow your appetite in deciding how much food to eat? The answer depends on your appetite. If it is healthy and well trained, it may be safely followed. But if your appetite has been spoiled with candy and other sweets, it is a very poor guide to eating the right amounts of other foods. Scientists have a much better way of deciding how much food a person should eat. They have found out how much energy different foods provide. They have also studied many people to find out how much energy is needed to do different things. From these facts, scientists have figured out how much food people of different ages or having different activities should eat.

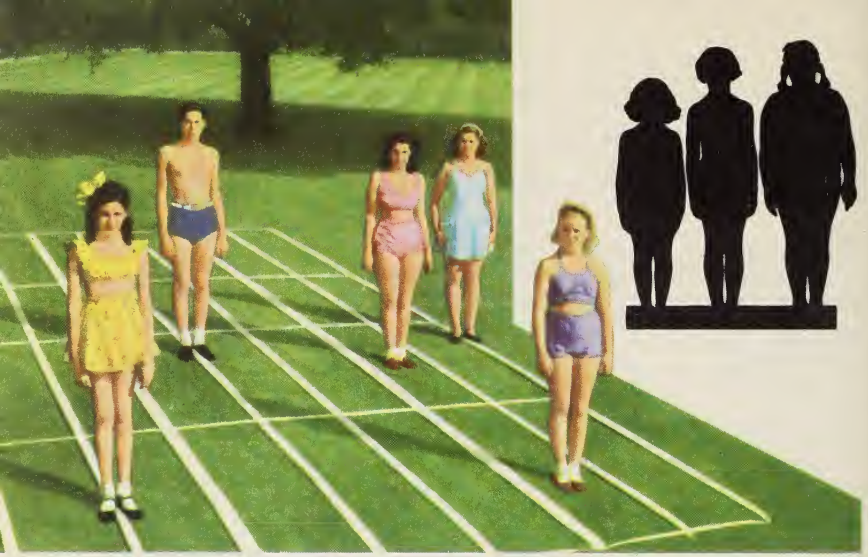
When fats, carbohydrates, or proteins are oxidized in your cells, energy is produced. To find out how much energy a food provides, scientists measure the heat given off when the food is burned as completely as it can be. This heat energy is measured in *calories* (kal′ə riz). One *calorie* is the amount of heat needed to raise the temperature of one pound of water about 4° F. The amount of energy produced depends on the kind of food that is oxidized. Fats produce more than twice as much energy as the same amount of carbohydrates or proteins. One ounce of pure

Calories in portions of common foods

Food	Portion	Calories
Bread and cereals		
Bran flakes	½ cup	50
Bread, rye	2 small slices	100
Bread, white	1 slice	75
Bread, whole-wheat	1 slice	75
Corn bread	2-inch square	120
Corn flakes	1 cup	80
Crackers, graham	3	120
Crackers, soda	2	50
Grapenuts	¼ cup	100
Macaroni	¾ cup	100
Muffin	1	110
Oatmeal, cooked	½ cup	75
Rice, cooked	¾ cup	100
Ryecrisp	3 wafers	50
Shredded wheat	1 biscuit	100
Sweet roll	1	120
Toast, French	1 slice	150
Waffle	1	225
Candies and desserts		
Brownie	2-inch square	100
Cake, chocolate	1 small slice	200
Cake, fruit	1 slice	125
Cake, sponge	1 slice	100
Chocolate bar	1 small	350
Chocolate fudge	1 piece	100
Chocolate pudding	½ cup	200
Custard, plain	½ cup	100
Doughnut, plain	1	200
Gingerbread	2-inch square	200
Ice-cream soda	1 glass	350
Ice cream, vanilla	½ cup	150
Jams, jellies	1 teaspoon	30
Jello	1 cup	75
Marshmallow	1	20
Oatmeal cookie	1	50
Pie, apple or berry	⅙ pie	350
Pie, mince	⅙ pie	350
Sugar, granulated	1 teaspoon	25
Dairy products		
Butter (or margarine)	1 pat (½ ounce)	100
Cheese, American	1½-inch cube	100
Cheese, cottage	2 tablespoons	50
Cheese, cream	1 ounce	105
Cream, plain	1 tablespoon	30
Cream, whipped	1 tablespoon	50
Egg, boiled	1	70
Milk, evaporated	1 tablespoon	20
Milk, skimmed	1 glass	85
Milk, whole	1 glass	170
Drinks		
Cocoa (all milk)	1 cup	180
Cola	1 glass	100
Lemonade	1 small glass	75
Malted milk	1 small glass	400
Fruits		
Apple, baked	1	200
Apple, raw	1 large	100
Apricots, canned	5	125
Banana	1 small	100
Cantaloupe	½	50
Cherries, fresh	10	50
Dates, dried	4	100
Figs, dried	2 large	100
Grapefruit	½	50
Grapes, Tokay	½ cup	75
Lemon	1 medium	30
Orange	1 medium	80
Orange juice	½ cup	65
Peach, fresh	1 large	50
Pear, fresh	1 medium	50
Pineapple, canned	2 slices	100
Plums, fresh	3 medium	55
Prunes, stewed	4	200
Raisins	¼ cup	100
Strawberries	¾ cup	35
Watermelon	6-inch slice	185

Calories in portions of common foods

Food	Portion	Calories
Meats		
Bacon, broiled	4 slices	100
Beef, dried	½ cup	125
Beef, ground	1 small patty	100
Beef roast	1 slice	100
Chicken, creamed	½ cup	200
Chicken, roast	3 slices, white	190
Duck, roast	3 slices	300
Frankfurter	1 small	100
Ham, baked	1 slice (no fat)	100
Lamb chop, broiled	1 medium	100
Lamb, roast	1 slice	100
Liver, calves	1 slice	150
Pork chop	1 medium	200
Pork roast	1 slice	170
Sausage, pork	1 small patty	150
Veal, roast	1 slice	100
Turkey, roast	1 slice, white	100
Nuts		
Almonds	10 to 12	100
Brazil	1 medium	50
Coconut	3 tablespoons	100
Peanuts, salted	18	100
Peanut butter	1 tablespoon	100
Pecans	8 to 10 halves	100
Walnuts	10 halves	100
Salads		
Cabbage slaw	½ cup	35
Combination, fruit	½ cup	110
Combination, vegetable	½ cup	90
Fruit gelatin	½ cup	110
Tomato and lettuce	1 tomato	35
Salad dressings		
French dressing	1 tablespoon	75
Mayonnaise	1 tablespoon	100
Olive oil	1 tablespoon	100
Thousand Island	1 tablespoon	100
Seafoods		
Oysters, raw	5 medium	100
Perch	2 medium	50
Salmon, canned	½ cup	100
Sardines, canned	3 medium	60
Shrimp	5 to 8	50
Trout, lake	1 large piece	125
Tuna, canned	½ cup	155
Soups		
Chicken, with rice	1 cup	100
Consomme	1 cup	40
Mushroom	1 cup	200
Pea	1 cup	200
Potato	1 cup	275
Tomato	1 cup	230
Vegetable	1 cup	100
Vegetables		
Asparagus, fresh	6 stalks	15
Beans, baked	½ cup	115
Beans, lima	½ cup	100
Beans, string	½ cup	30
Beets, fresh	2 medium	50
Broccoli	3 stalks	55
Brussels sprouts	6 medium	40
Cabbage, shredded	1 cup	30
Carrot, fresh	1 large	45
Cauliflower	1 small head	100
Celery	2 stalks	10
Corn, on cob	1 ear	100
Lettuce	2 large leaves	5
Onions, dry	1 large	50
Peas, fresh	½ cup	60
Potato, baked	1 medium	100
Potato, sweet, baked	1 small	125
Spinach	1 cup	50
Tomato, raw	1	35
Tomatoes, stewed	½ cup	20
Turnips	½ cup	35



The black outlines of the three little girls show how differently bodies may be built. How would you describe these body builds? The older boy and girls in the other picture are grouped according to body builds. Do you see the same kinds as in the younger children?

fat gives out about 264 calories, while an ounce of pure carbohydrate or protein gives out only about 116 calories. The table on pages 318 and 319 shows the number of calories in portions of common foods.

To find out how much energy a person needs, scientists weigh the oxygen that he takes in and the carbon dioxide that he gives out. When scientists know these facts, they can figure out how much energy a person should get from his food. This energy is also measured in calories. The table on page 321 shows the number of calories needed by different people. Experts who plan meals refer to a table like this to find out how many calories a person needs every day. Then the amounts of food that will give about the right number of calories for each meal are chosen from a table like the one on pages 318 and 319.

You cannot eat all the time just to keep your body supplied with energy. So some of the food that you eat is stored in your body for future use. Part of this food is stored in your cells as sugar. It is ready to be used whenever your body needs energy quickly. The rest of this food is changed into fat. A certain

amount of fat is healthful. Whenever it is needed, it can provide your body with much energy. It also protects your skin, bones, muscles, and nerves from injury. However, many people overeat and become too fat. Overeating makes the body digest more food than it needs, and the extra fat puts an added strain on the heart.

Probably you do not need to count the calories in the foods that you eat. But you should eat enough food to keep your body supplied with energy throughout the day. Of course, you should also eat enough food to gain weight as you grow. Perhaps you are not so tall or do not weigh so much as other boys and girls in your class. There is nothing unusual about this. You have often noticed that people are built differently. Some are tall and thin, while others are short and stocky. Still others are somewhere in between in height and weight.

Scientists have studied and measured thousands of children. They have found that children can be put into groups having different body builds. Scientists have also found what heights and weights children of different body builds usually have at different ages. When your doctor or the school nurse has decided which body build you have, he can tell whether you are growing as you should.

Calories recommended for different persons

Person	Activity or Age	Calories per day
Man	Desk work	2500
	Fairly active	3000
	Very active	4500
Woman	Desk work	2100
	Fairly active	2500
	Very active	3000
Boy	10-12 years	2500
	13-15 years	3200
	16-20 years	3800
Girl	10-12 years	2500
	13-15 years	2800
	16-20 years	2400

Every time you are measured and weighed, your height and weight are compared with what they were before. So you are really compared with yourself and not with someone else. In this way, the doctor or nurse can tell whether you are eating the right amount of food to make you grow properly. If your weight is far below what it should be for your age and body build, you should probably eat more food. But if you are much heavier than you should be for your age and body build, you may need to eat less food, especially carbohydrates and fats.

The important thing for you to do now is to form good eating habits. Here are some simple suggestions that will help your body make the best use of the food you eat.

1 *Eat the basic seven every day.* If you eat foods from each basic group every day, you will have a well-balanced diet.
2 *Eat three meals a day at regular hours.* If you are very active, you may want to eat a light lunch of easily digested food in the middle of the morning and again in the middle of the afternoon. Some fruit or a glass of milk is the best thing to have at these times.
3 *Do not spoil your appetite with sweets.* Sugar may sometimes give your body quick energy, but you do not need much sugar in your diet. Jams, jellies, honey, syrups, candy, cookies, cake, pie, and all sweet desserts contain sugar. You will probably have one of these foods every day, but you should have them as part of a meal rather than between meals. Eating too many sweets spoils your appetite for the other foods that your body needs.
4 *Drink at least four glasses of water every day.* The solid and liquid foods that you eat provide your body with some water. If you wish, drink water with your meals but do not wash your food down.
5 *Do not let your dislike for certain foods be a guide to your diet.* Quite often people dislike vegetables such as carrots only because someone they know dislikes these vegetables.
6 *Do not rush through your meals.* Give yourself enough time to enjoy your meals with your family and friends. Always try to make mealtime a cheerful time.
7 *Get plenty of fresh air, sunshine, exercise, and sleep.* These will all help you get the most from your food.

SELF-TESTING EXERCISES

1 **a** State two things that scientists had to learn before they could figure out how much food a person needs.

b How did scientists find out each of these things?

2 **a** What is meant by a calorie?

b For what two purposes do scientists who study food use the calorie?

3 **a** How is your body kept supplied with energy between meals?

b If you eat more food than your body needs, what happens to some of this food?

c Is this condition healthy or unhealthy? Explain your answer.

4 **a** How can you decide how much food you should eat?

b How does a doctor or school nurse tell whether you are eating the right amounts of food?

PROBLEMS TO SOLVE

1 Are the people in the pictures below making the best use of their food? Look at each picture carefully and explain your answers.

2 Explain why different people need different amounts of food. Give as many reasons as you can.

3 **a** Keep a record of all the food that you eat in one day. Then use the table on pages 318 and 319 to find about how many calories of energy this food provides.

b Now refer to the table on page 321. Are you getting the right amount of energy in your food?

4 **a** How can you find out whether you are eating foods from each of the seven basic groups every day?

b Should you eat more of some foods and less of others? Why do you think so?

5 **a** When people are sick and cannot eat much food, where do they get energy?

b Why do their bodies become thinner?

6 Do you think that you need more food on some days than on others? Explain your answer.

7 From the table on page 321, find out how many calories of energy you need in a day. Then using the chart on page 313 and the table on pages 318 and 319, plan your meals for one day so that you will have a well-balanced diet and the right amount of energy for what you do that day.

8 For lunch, one girl had a jelly sandwich made with plain white bread, a candy bar, and a bottle of "pop." Another girl had a peanut-butter sandwich made with enriched bread, a vegetable salad, a baked apple, and a glass of milk. Which girl chose the better lunch? Give your reasons.

9 List the seven basic groups of foods shown in the chart on page 313. Then for each group name at least two foods shown in the pictures on pages 288 and 289.

SUMMARY EXERCISES

1 Make a list of the big ideas that you learned in this unit. Be sure to write them as complete sentences.

2 Show that you understand what the following words mean: food, energy, digestion, carbohydrates, fats, proteins, minerals, vitamins, fortified foods, restored foods, pellagra, deficiency disease, diet, ultraviolet rays, calorie.

ADDITIONAL ACTIVITIES

1 Cut out plans for meals in newspapers and magazines. Then study the plans to see how they provide a well-balanced diet.

2 Find out whether you are overweight or underweight for your age and body build. Are you getting the right amount of food to grow properly?

3 Plan and do an experiment to find out whether you weigh more or less after an hour of vigorous exercise. How can you explain the change in your weight? Weigh yourself again 24 hours later. Is your weight about the same as it was before you exercised? Why?

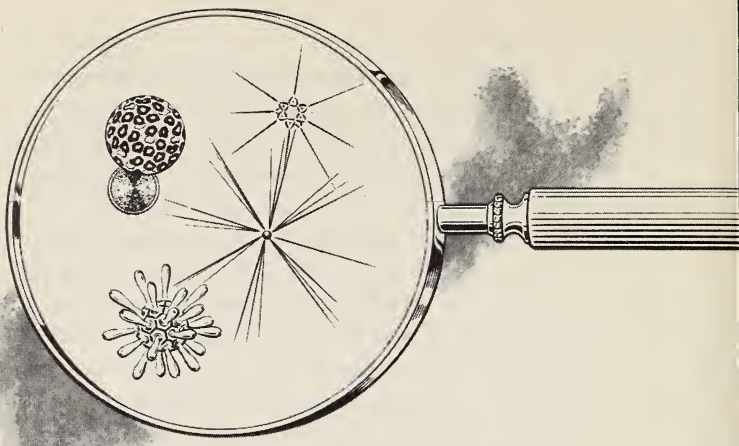
4 Collect labels from bread wrappers, cereal boxes, and other empty food containers. What information is given on the labels?

5 Visit a grocery store to find out how food is kept fresh and clean.

6 Take some milk apart to find some of the materials that it contains. Remove the cream, or fat, from the top of the bottle. Churn the cream into butter by shaking it in a glass jar with a tight cover or by beating it with an egg beater. Let the skim milk stand until it is sour. Then heat it gently. The white, fluffy material is curd, which contains proteins. Strain the curd, salt it, and you have some cottage cheese. The watery liquid is whey. Heat the whey in a shallow pan until the liquid evaporates. The sticky material that is left contains sugar, calcium, and phosphorus.

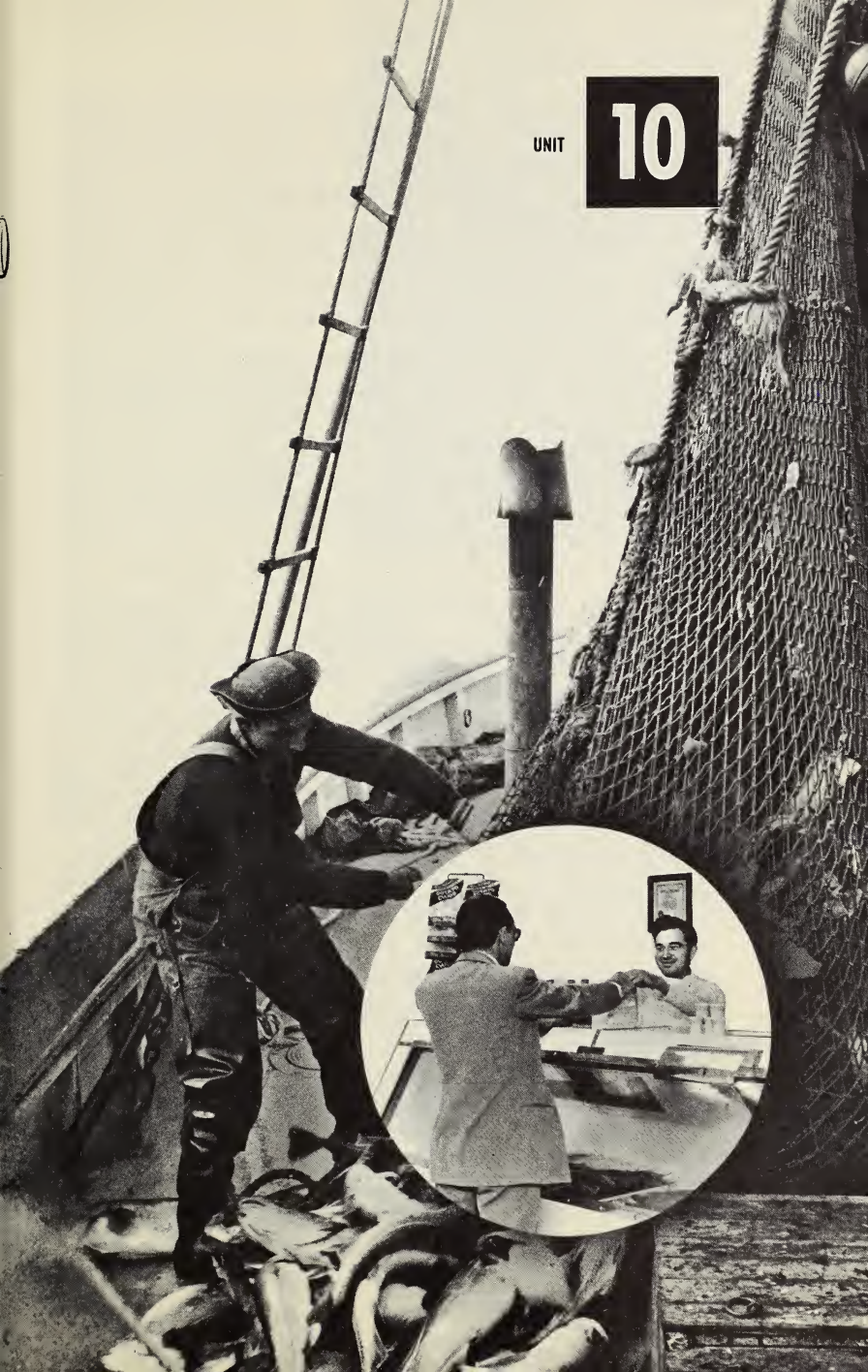
7 Do an experiment with white rats to find out what effect diet has on growth and health. Get some white rats that are about the same age and size. Divide the rats into two groups and keep each group in a separate cage. Weigh the rats and record their weights on a chart. Feed one group lean meat, bread, potato, and plenty of water. Feed the other group the same things but also give them raw and cooked vegetables and milk. Give both groups fresh food and water every day and keep the cages clean. Weigh the rats once each week and record their weights on the chart. Watch the rats carefully as they grow. How soon can you begin to notice a difference between the two groups? Which group looks healthier? What does this experiment show?

8 In reference books, read about the following topics: digestion, minerals, milk, vitamins, amino acids, metabolism, food processing, cheese making, cooking.



How do living things depend on each other?

Floating in the ocean are many millions of very tiny algae, protozoans, and crustaceans. The protozoans and crustaceans eat the algae. Very small fish use the little animals for food. Large fish eat the small fish. Fishermen catch the larger fish for us to eat. This chain of happenings shows one way in which living things depend on each other. Can you think of other ways?


UNIT
10

LOOKING AHEAD TO UNIT 10

You live in some kind of community. It may be a farming community, a small town, or a big city. The people in your community depend on each other. Not all of them do the same kind of work, but each one fits into the life of the community and also into the life of other communities. Farmers, miners, factory workers, storekeepers, and many others all help provide the things that we need and use. Though our communities may be different in some ways, they are all alike in this way: Every community must have a supply of food. So there are always some people who provide food for the community. They may raise the plants and animals that are used for food, or they may run stores where food is sold.

If you watch living things when you are outdoors, you will find that they also live in communities. Groups of plants and animals live together, and each one depends on the others in the community. Just as in our communities, every community of plants and animals must have a supply of food. Food does the same things for plants and animals as it does for you. It provides the energy and materials that they need and use. To stay alive, every plant and animal must have food.

You already know where this food comes from. Only plants with the green coloring matter called chlorophyll can make their own food. Most seed plants and all plants such as ferns, mosses, and algae contain chlorophyll. All other living things must get food directly or indirectly from these green plants. So there must be green plants in every community of living things. Green plants not only provide food for the living things in their community, but they also provide directly or indirectly the food that you eat. Like every other living thing, you depend on green plants for food. From green plants also come many of the materials that we use for clothing, shelter, and fuel.

Green plants depend on other groups of living things in their community. To keep on making food, green plants must have these other plants and animals. If there were only green plants in a community, they would soon use up all the materials from which food is made. But other plants and animals put these materials back

Perhaps you think of earthworms only as fish bait. But they really do a much more important job in our community. As they burrow through the soil, they fertilize it and loosen it so that air and water get down into the soil more easily. Our plants grow better, and we have better crops.

where they can be used again by green plants to make more food. So every community of living things must have different groups of plants and animals. Each one does some kind of work that is needed to keep the community alive.

Life in a community of plants and animals is always a struggle for existence. Even if you do not notice this struggle when you are outdoors, it is going on everywhere around you. Cold, heat, dry weather, and many other conditions make it hard for a plant or animal to stay alive. And besides helping each other, living things also harm each other. They are always competing for food, air, water, light, and a place to live. If a plant or animal is to stay alive and produce more living things like itself, it must keep from being eaten or otherwise killed. The strongest plants and animals, or those that work together best, live. The weakest plants and animals, or those that do not work together, die.

Communities of plants and animals are very different from each other, just as city communities are different from farming communities. But all communities of plants and animals are alike in some important ways. When you discover how all these communities are alike, you can better understand the community in which

This man has a Christmas tree farm. To help his trees grow well, he digs out the briars and wild shrubs that have grown up around the Christmas trees. Why do you think he must do this?

you live. For you are a member of a community of plants and animals just as truly as you are a member of a community of people. This unit tells you how living things depend on each other. As you study the unit, you will learn some of the important reasons why living things need and use other living things. You will also find answers to such questions as these: How do green plants make food? How do plants and animals live together? How do living things keep a balance of numbers?

1 How do green plants make food?

WHERE DO GREEN PLANTS GET MATERIALS TO MAKE FOOD? Most of our food comes from green plants that have seeds or from animals that eat these plants. You know that seed plants have roots, stems, and leaves. And you probably know that each of these parts has something to do with making food. However, not all green plants have roots, stems, and leaves. Yet they all need the same materials to make food, and they all make food in about the same way. So if you learn how plants with roots, stems, and leaves make food, you will understand how other green plants make food, too.

Inside the covering of a seed, there is a tiny young plant with food stored around it. When the plant begins to grow, the covering bursts. Roots go down into the soil, and the stem and leaves push up into the air. The food stored in the seed is soon used up. To keep on growing, the plant must make its own food. Where does it get the materials to do this? They must come from the soil or the air or from both. There is no other place from which the materials could come.

From green plants we can get carbohydrates, fats, proteins, minerals, vitamins, and water. All these kinds of food are compounds. Sugar and starch are different compounds, but they are both carbohydrates. They are made from the same three elements—carbon, hydrogen, and oxygen—combined in almost the same way. Some of the sugar that you eat comes from sugar cane or sugar beets. There is much starch in potatoes and also in corn, wheat, and rice. The roots of all these plants grow in the soil, and their stems and leaves grow in the air. Do the plants get sugar and starch from the air or the soil?

Chemists cannot find these compounds when they analyze either air or soil. But they can find all three of the elements that are in sugar and starch. These facts seem to have only one explanation: The plants take materials from the soil and the air and then make the materials into sugar and starch. In other words, the plants make sugar and starch from materials that they get from the soil and the air. They use these carbohydrates for food.

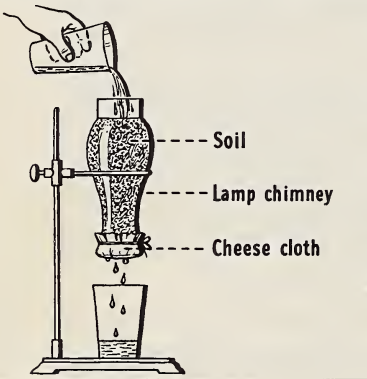
To make carbohydrates, green plants must have materials that contain the three elements—carbon, hydrogen, and oxygen. In the soil around the roots, there is water (H_2O), a compound of hydrogen and oxygen. Around the stems and leaves, there is air. You have learned that air is a mixture of gases. One of the gases in the air is carbon dioxide (CO_2), a compound of carbon and oxygen. The roots of green plants take in water from the soil, and their leaves take in carbon dioxide from the air. From water in the soil and carbon dioxide in the air, green plants get the three elements that they need to make carbohydrates.

However, carbohydrates are not the only kind of food that green plants make. Fats are made of the same three elements as

carbohydrates, and green plants can change carbohydrates into fats. To make other kinds of food, green plants need some materials besides carbon dioxide and water. Proteins have all three of the elements that are in carbohydrates and fats. But proteins also contain nitrogen and sometimes sulphur and phosphorus. To make proteins, green plants must have these other elements.

Nitrogen, sulphur, phosphorus, and at least a dozen more elements that green plants need, all come from the soil. These elements are in compounds called minerals. The minerals dissolve in water in the soil. Then the roots take in the solution of water and minerals. Only the minerals that dissolve in water can get into the plants. If you do Experiment 1, you can find out whether soil contains minerals that dissolve in water.

Experiment 1 Does soil contain minerals that dissolve in water?



1 Pour in enough distilled water so that about a glass of water will filter through.

2 Boil the water that has come through until it is all gone.

3 What is left after boiling? Where do you think this material came from? Does it dissolve in water? How do you know?

4 How can you do an experiment to show that the material was not in the distilled water? Try the experiment and see what happens.

In Unit 8 you learned that the bodies of plants and animals contain about twenty different elements. All of these elements are found in either the soil or the air. But you cannot use the materials in soil or air for food. You and all other living things must get food directly or indirectly from green plants. Only green plants can make food from the materials in the soil and the air. Everything in a green plant is made from carbon dioxide, water, and minerals.

SELF-TESTING EXERCISES

1 How do scientists know that green plants make their own food instead of getting it from the soil and the air?

2 **a** What three elements are carbohydrates made of?
b Where do green plants get these elements?

3 **a** What elements do green plants need to make fats?
b Where do these elements come from?

4 **a** What elements must green plants have to make proteins?
b Where do green plants get these elements?

5 Why must minerals be dissolved before plants can use them?

HOW DO GREEN PLANTS GET WATER AND MINERALS? If you ever tried to pull up a large weed or a small tree, you probably found that its roots had a very strong hold in the soil. Roots hold a plant in place, or anchor it. In many plants, the roots take up more space than the parts above the ground. Some kinds of plants have one large main root, called a *taproot,* with several smaller roots branching off from it. Beets, carrots, radishes, and turnips all have taproots. Other kinds of plants, such as grass, corn, and wheat, have many main roots that are all about the same size. These are called *fibrous* (fī'brəs) roots. From the fibrous roots many smaller roots branch off. In Observation 1 you can see how the roots of plants are arranged.

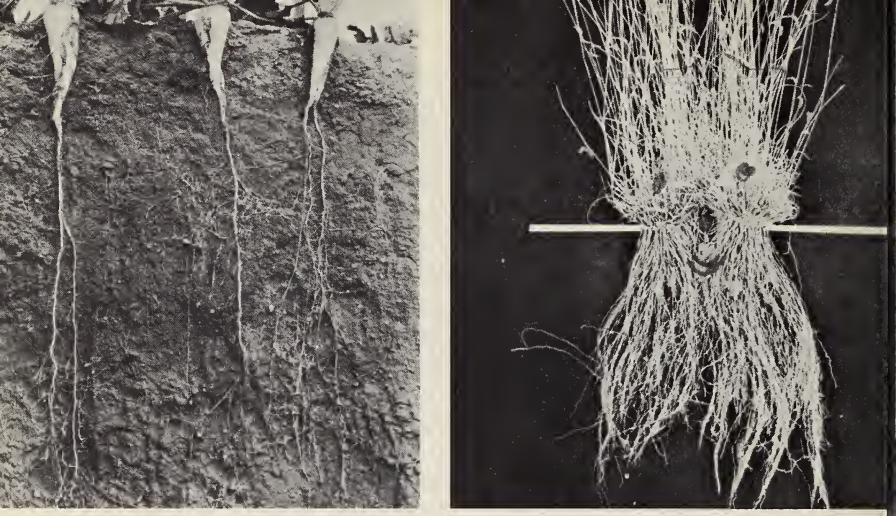
Observation 1 How are the roots of plants arranged?

What you need: Garden (or crop) plant growing in the soil; water; pail; spade (or trowel); ruler.

What you do: The day before you dig up the plant, pour plenty of water around it so that the soil is thoroughly wet. The next day, dig up the plant with a spade or trowel. Leave plenty of soil clinging to the roots. Did you get all the roots? Or were some broken off and left in the soil?

Now put the plant in a pail of water and gently wash away the soil from the roots. Notice the main root or roots and any smaller roots branching off from them. Does the plant have a taproot or fibrous roots?

With a ruler, measure the length of some of the roots. Why do you think a plant needs such long roots?



On the left are sugar beets, and on the right is a grass plant. What kind of roots has each of these plants?

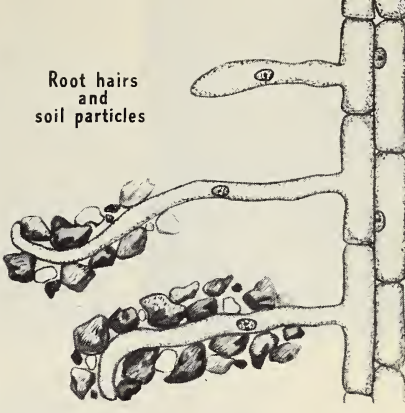
When you dig up a plant, most of the roots that you see have a thick, tough covering. Water and dissolved minerals cannot get into a root through this covering. The parts of a root that take in water and minerals are usually left in the soil, and you do not see them. They are called root hairs, and they look like white fuzz. Root hairs cover an inch or two just back of the tip of each root. The tiny white root on which they grow is hardly larger than a thread. In Observation 2 you can see some root hairs.

Observation 2 What do root hairs look like?

What you need: Seeds (lima bean, pea, corn, radish, cabbage, or mustard); water; blotting paper (or towel paper); shallow dish; piece of glass; magnifying glass.

What you do: Put about a dozen seeds between pieces of moist blotting paper or towel paper in a shallow dish. Cover the dish with a piece of glass to keep the paper moist. Leave the dish in a warm place for at least two days. When the seeds have sprouted, look at one of the tiny roots. Do you see the white fuzz along the root? This white fuzz is made up of root hairs. If you cannot see it clearly, use a magnifying glass.

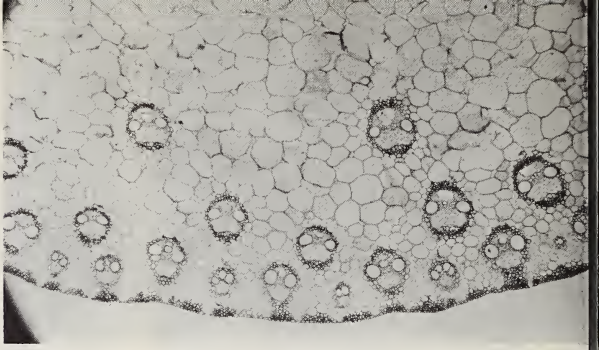
Where are the root hairs longest? Where are they shortest? Are there any root hairs at the very tip of the root?



If you grew corn seedlings, you probably saw a fuzz of root hairs like this. The drawing shows how each hair grows and touches the soil particles.

Each root hair is a hollow tube with thin walls that grows out from a cell on the outside of the root. Root hairs contain protoplasm and the watery sap of the plant, because they are part of the cells of the root. Of course, the ends of the root hairs are closed to keep in the sap and protoplasm. Water in the soil makes the root hairs grow. Like tiny fingers, they reach out and wrap themselves around the particles of soil. Then they soak up the water around each particle through their thin walls. The water has minerals from the soil dissolved in it. Because there are so many root hairs, they can soak up all the water and minerals that a green plant needs to make food.

You can see why it is hard to move a plant without injuring its roots. When a plant is dug up, many small roots and most of the root hairs are broken off and left in the soil. If you leave a ball of soil around the roots, it will help protect them. But no matter how careful you are, many small roots and most of the root hairs will be broken off. The plant cannot take in much water until it grows new root hairs. When a gardener moves a plant, he often cuts off some of the leaves and stems. He does this to keep the plant from losing too much water. With fewer leaves, less water will evaporate from the plant while it is growing new root hairs. When it has enough root hairs, it can quickly grow new leaves and stems.



Part of the celery stalk on the left has been cut away, leaving the bundles that run up through the stem. On the right is a thin slice across a corn stem. The water-carrying tubes are in the small groups of cells that you see scattered through the slice.

After water and dissolved minerals get into the roots, they must be carried up to the leaves, where food is made. Then the food must be carried down to the stems and roots. So a green plant must have some way of carrying materials all through it. In Unit 2 you learned that plants with leaves, stems, and roots also have tubes which carry water. These tubes run up through the roots and the stems into the leaves, carrying water and dissolved minerals. Other tubes carry food down from the leaves to other parts of a green plant. In Observation 3 you can see where the water-carrying tubes of plants are.

Observation 3 Where are the water-carrying tubes of plants?

What you need: Bunch of celery; pan; water; sharp knife; glass (or jar); red ink; tweezers.

What you do: Pick out a fresh stalk, or stem, of celery with several leaves on it. Put the lower end of the stalk into a pan of water. With a sharp knife cut off about an inch from the bottom of the stalk under water. Then set the stalk in a glass or jar of water that has been thoroughly colored with red ink. Leave the stalk in the colored water for several hours or overnight. What happens?

Break the stem or cut across it in several places. Can you see where the ink in the water colored the stem red? Find the tubes that carry water. Then pick the stem apart with tweezers and follow the red streaks up through the stem to the leaves. Can you see where the colored water has gone into the leaves?

Hold the leaves up to the light and compare them with some leaves from another stalk of celery. Can you see the small veins that have turned pink?

The water-carrying tubes are in bundles of cells. Some of the cells in each bundle are tough fibers that make the bundle strong. Other cells form the hollow tubes that carry water, dissolved minerals, and food all through the plant. If you pull a dry cornstalk apart, you can see the threadlike bundles of fibers and tubes. The strings in celery are also bundles like these. Some plants have the bundles scattered throughout the stem, as in corn and celery. Other plants have the bundles just under the outer covering of the stem, as in trees and shrubs. The bundles of fibers and tubes help support the stem.

The water-carrying tubes run up into the leaves. If you look carefully at a green leaf, you will see that it has veins all through it. You can see the veins more clearly by holding the leaf up to the light. In some kinds of plants, the veins all run in the same direction. In other kinds, they form a network. The veins of a leaf are really bundles of fibers and tubes like those in the stem. They form a framework that helps hold the leaf out in the sunlight, and they carry materials to and from the leaf. Every part of a leaf is very close to a vein. So every cell in a leaf is very close to a water-carrying tube.

The X-ray picture of these leaves and flowers shows their inside structure. Find the bundles of tubes that run into all parts of the leaves and flowers.

SELF-TESTING EXERCISES

1 Complete each sentence below with the word or words that make it a true statement.

a The parts of a root that take in water and dissolved minerals are called _____.

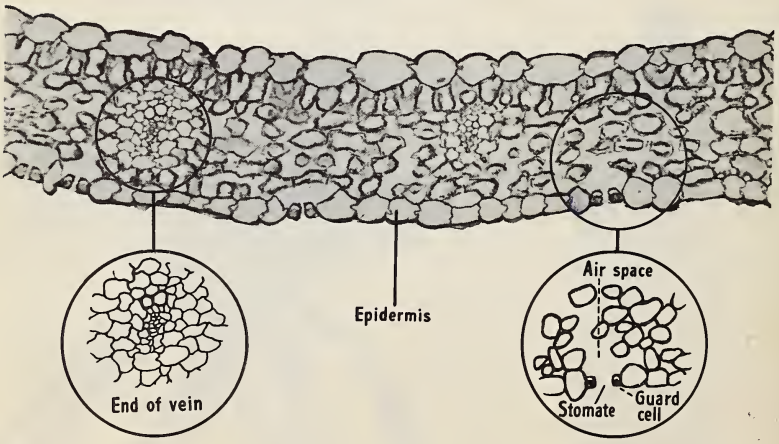
b After water and minerals get into the roots, they must be carried up through the _____ into the _____.

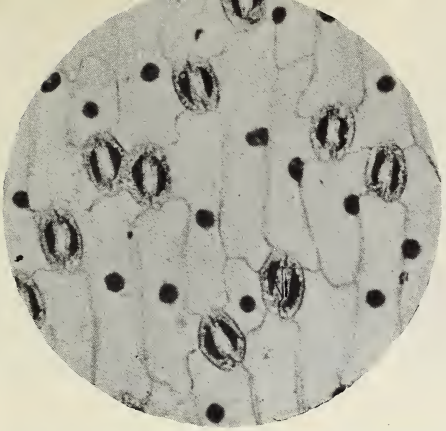
c There are water-carrying tubes in the _____.

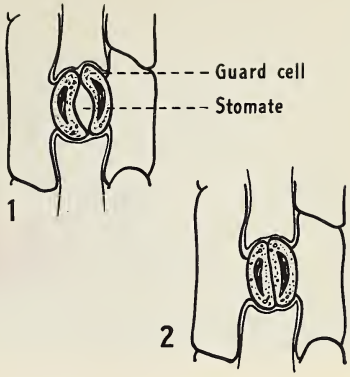
2 Why does a plant need many roots?

3 How does food get from the leaves to the stems and roots?

HOW IS FOOD MADE IN A GREEN LEAF? You have learned how water and minerals get from the soil up into the leaves, where food is made. To make food, a leaf must have one more material—carbon dioxide. This gas is in the air all around the leaf. By studying the picture on this page, you can find out how carbon dioxide gets into the cells that make food in the leaf. The picture shows a very thin slice cut across a leaf from top to bottom. To see the cells as they are shown, you would have to look at this slice of a leaf through a powerful microscope. In the picture you can see the end of a vein. Inside the vein are the tubes that bring water and minerals to the leaf and carry away food.







On the left you see the stomates of a lily leaf. In picture 1 on the right the stomate is open. Picture 2 shows how the guard cells close the stomate.

The upper and lower surfaces of the leaf are covered with a single layer of cells called the *epidermis* (ep′i dėr′mis). The cells of the epidermis are clear like glass. So sunlight can shine right through the cells into the leaf as if it were a greenhouse. The outside of the epidermis has a waxy coating that is waterproof. This coating helps keep water from evaporating from the cells of the epidermis.

In the lower epidermis, you can see the tiny openings into the leaf. Each opening is called a *stomate* (stō′māt). It can be opened or closed like a little mouth. Around each stomate are two *guard cells* shaped somewhat like kidney beans. The guard cells keep the leaf from drying out by controlling the amount of water that evaporates. When the guard cells have much water in them, they swell up and open the stomates. But when they have little water in them, they flatten out and close the stomates.

Air, with its carbon dioxide, gets into the leaf through millions of stomates. Then the air goes into the spaces between the cells that make food. The carbon dioxide dissolves in the water on the cell walls and passes into the cells with the water. The cells that make food contain the green material chlorophyll. The leaf looks green because the color of the chlorophyll shows through the clear epidermis. To make food, the cells of the leaf must have chlorophyll.

You already know that a green plant makes food from carbon dioxide, water, and minerals. Carbon dioxide comes from the air, while water and minerals come from the soil. Inside a leaf, the cells that contain chlorophyll make carbon dioxide and water into carbohydrates. This is a chemical change. But it will not take place unless the leaf has one more thing—light. From Unit 5 you remember that light can cause chemical changes. Like heat, light is a form of energy. If you do Experiment 2, you can find out whether light is needed to make starch in a green leaf.

Experiment 2 Is light needed to make starch in a green leaf?

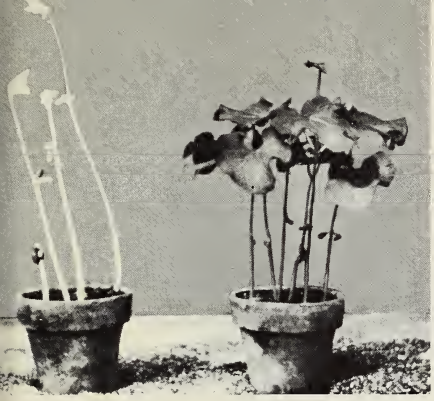
What you need: Potted geranium (or nasturtium) plant; slices of cork (or small pieces of black paper); pins; pan; water; gas burner (or other source of heat); matches; beaker; 95% grain alcohol (or rubbing alcohol); dilute iodine solution; shallow dish; piece of cardboard (or glass).

What you do: Keep the plant in the dark for at least two days. Then pin two slices of cork or pieces of black paper on opposite sides of a leaf as shown in the picture. Fix several leaves in this way. If the leaf is too heavy to hold itself up, prop it up. Now set the plant in the bright sunlight for several hours. Then break off a leaf and dip it into a pan of boiling water for a short time. The heat kills the leaf.

To soak the green color out of the leaf, put the leaf into a beaker of alcohol and set the beaker in a pan of boiling water. DO NOT PUT THE BEAKER DIRECTLY OVER THE BURNER. ALCOHOL CATCHES FIRE EASILY. Let the leaf stay in the alcohol until all the green color is gone. You may need to use fresh alcohol to get out all the color. Now soak the leaf in some iodine solution in a shallow dish. Then spread the leaf out on a piece of cardboard or glass.

Does part of the leaf turn blue or blue-black instead of brown? Which part? What material does this show is in the leaf? Answer the question of the experiment. To check your results, test the other leaves that you fixed.

After a green plant has been in the light for some time, there is starch in the leaves. Scientists know that the starch is made from sugar, which has been made by the plant. Many experiments show that a leaf makes carbohydrates only when it is in the light. If



One of each of these two pairs of plants was grown in the dark. Which one do you think it was? Explain your answer.

a green plant is kept in the dark for a long time, it will die because it can no longer make its own food. Green plants must have light to make chlorophyll, and they must also have light to change carbon dioxide and water into carbohydrates.

You can now understand why a green leaf is sometimes called a food factory. It makes a product (carbohydrates) from raw materials (carbon dioxide and water). The raw materials are changed into new materials. The change takes place in the cells that contain chlorophyll. For the change to take place, light must shine on the chlorophyll. The chlorophyll is the machinery of the factory. The protoplasm inside the cells takes care of the factory and its machinery. The energy for running the machinery comes from sunlight.

You cannot get energy out of carbon dioxide and water. But you can get energy out of carbohydrates, fats, and proteins. Where does this energy come from? Some of the energy from sunlight is taken in by the chlorophyll and stored in carbohydrates. Then in some way green plants change carbohydrates into fats and proteins. When you eat any of these foods, you can get the energy out of them. So the energy that you and all other living things get from food really comes from the energy in sunlight. The sun is the real source of most of the energy that we use.

Light from the sun shines through the clear epidermis of a leaf into the cells that contain chlorophyll. In these cells, light causes a chemical change that makes carbon dioxide and water into carbohydrates. Scientists have a name for this chemical change. They call it *photosynthesis* (fō′tō sin′thi sis). Photo means light, and synthesis means putting together. So photosynthesis means putting together by light. For photosynthesis to take place, a plant must have four things: (1) carbon dioxide, (2) water, (3) chlorophyll, and (4) light.

No one understands exactly how food is made in a green plant, though scientists are discovering new facts all the time. They know that sugar is made from carbon dioxide and water during photosynthesis. Then some of the sugar is changed to starch and stored in the cells of the leaf. This is another chemical change. At night, some of the starch is changed back to sugar and carried away to the roots, stems, and seeds. You already know why starch must be changed to sugar. Sugar dissolves in water, but starch does not. Only materials that are dissolved in the watery sap can get into the cells of the plant. When dissolved sugar reaches the stems, roots, and seeds, it is usually changed to starch again. Then the starch is stored for later use.

Photosynthesis is one of the most important chemical changes that take place in our world. If photosynthesis did not take place, all living things would die. Very few plants and no animals can use the materials in soil and air for food. These materials must be changed into food before most living things can use them, and this change takes place only in green plants.

SELF-TESTING EXERCISES

1 Draw a diagram of a leaf. Show the epidermis, a vein, some stomates, guard cells, and cells where food is made. Put in some arrows to show how carbon dioxide and water get into the leaf and how food is carried away.
2 State two ways in which a leaf is kept from drying out.
3 How does carbon dioxide get into the cells of the leaf where food is made?
4 Why do leaves look green?

In Unit 9 you learned that white potatoes contain much starch. Study this picture and then explain how the starch got into the potatoes, which grow underground.

5 **a** When carbohydrates are made in a green plant, how do we know that a chemical change has taken place?
b For this change to take place, what four things must a plant have?

6 **a** Where do green plants get the energy to make carbohydrates?
b Where does the energy stored in carbohydrates and other kinds of food come from?

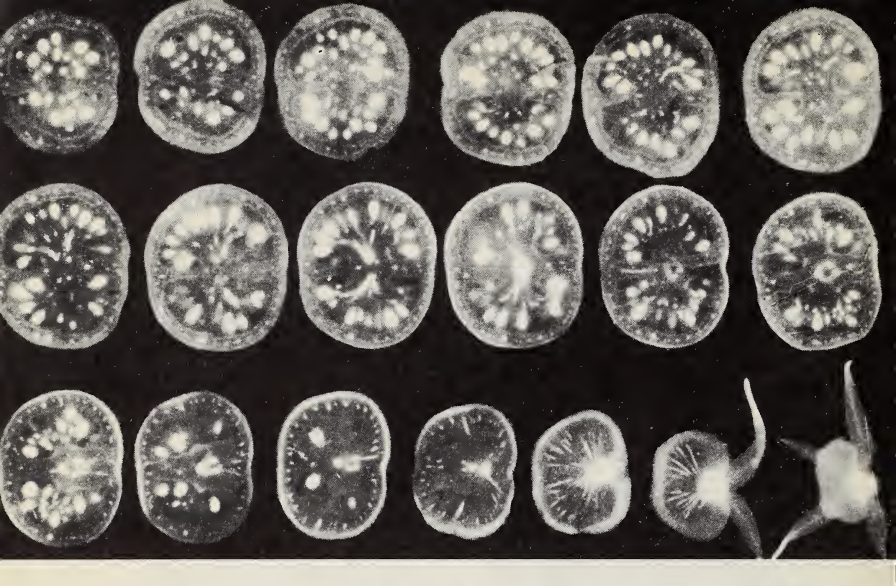
7 **a** What do scientists call the chemical change by which green plants make carbohydrates?
b What does this name mean?
c Why is this chemical change very important?

8 **a** In what form are carbohydrates usually stored in green plants?
b In what form are carbohydrates carried from one part of a plant to another? Why?

PROBLEMS TO SOLVE

1 Do you think this statement is true? *A huge sequoia tree 350 feet tall is made only from carbon dioxide, water, and minerals.* Explain your answer.

2 Why does a plant usually die if its main stem is broken?



The bright spots in the tomatoes were made by a certain kind of zinc. The tomatoes came from plants grown in a solution containing this kind of zinc. How did it get into the tomatoes?

3 Some plants have leaves that are spotted. Parts of each leaf are green, and other parts are nearly white. If you tested these leaves for starch after they were in the sunlight, where would you expect to find the starch? Give your reasons.

4 Peas and sweet corn are sweeter when newly picked than after they have been kept for a day. Explain.

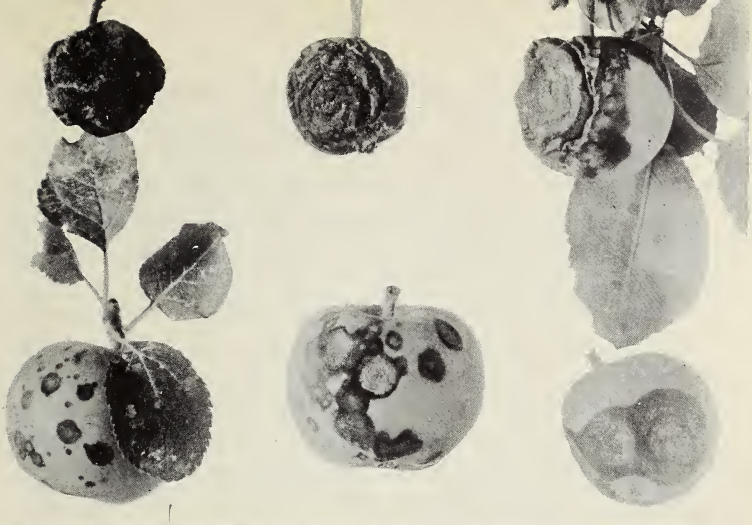
5 Farmers sometimes kill trees by girdling them. To girdle a tree, a farmer cuts a deep ring all around the trunk. Why do you think the tree dies?

6 For St. Patrick's Day, florists often make green carnations. How do you suppose the white flowers are made green?

7 Most of our coal was made from the dead bodies of treelike ferns that lived millions of years ago. Where did the energy that we get from coal really come from? Explain your answer.

8 Why do tomato plants droop, or wilt, for the first day after they have been transplanted?

9 After watering the lawn, a boy left the hose lying on the grass. Several days later, he noticed that the grass under the hose had turned yellow. Why do you think this happened?



The fungus that causes this disease of apples is a parasite. It often gets its food while the apple is still on the tree. As you can see, there sometimes is not much left of the apple.

How do plants and animals live together? 2

HOW DO OTHER LIVING THINGS GET FOOD FROM GREEN PLANTS? Food provides the energy and materials that plants and animals must have to stay alive. The energy in food really comes from the sun, while the materials in food come from the soil and the air. Only plants that contain chlorophyll can use sunlight to change water, minerals, and carbon dioxide into food. Because photosynthesis takes place only in green plants, there must be green plants in every community of living things. From these green plants, all other plants and animals in the community get food in some way. They can use the energy in this food, and they can also change the materials in it into other materials that they need.

Some kinds of animals get their food directly from green plants. Among these plant-eating animals are cows, horses, sheep, rabbits, squirrels, deer, and elephants. Many kinds of birds and insects also feed on green plants. All these animals can digest the food that they get from green plants and change it into the materials from

which their bodies are made. However, lions, tigers, wolves, owls, hawks, and many other kinds of animals eat meat. They would starve if they tried to live on green plants, because they cannot digest the food that green plants make. But they can digest the bodies of animals that eat green plants. So the meat-eating animals feed on the plant-eating animals. In one way or the other, all animals get their food from green plants.

Many kinds of plants get their food directly from green plants. Dodder is a yellow or orange plant that grows like a vine. Its seeds develop into new plants just as those of other seed plants do. But it has no noticeable leaves and little or no chlorophyll. So dodder cannot make its own food. When dodder touches a green plant, it winds itself tightly around the plant and sends in rootlike suckers. Through these suckers, it takes in food and water from the green plant. Dodder is a parasite because it lives on green plants and gets its food and water from them. Mistletoe, which grows on the branches of trees, is partly a parasite. It can make its own food because its green leaves contain chlorophyll. But mistletoe gets water and minerals from the tree on which it grows.

Mushrooms, molds, yeasts, bacteria, and all other fungi have no chlorophyll. So, of course, none of these plants can make its own

On the left is a piece of dodder twining about a plant stem. Find the tiny rootlike suckers. On the right is mistletoe growing on a branch.

food. A fungus must get its food from green plants or from animals. Some kinds of fungi are parasites. They live on or in the living plants and animals from which they get their food. Other kinds of fungi get their food from dead things or from materials that have come from living things. Any plant that gets its food in this way is called a *saprophyte* (sap′rō fīt). In Observation 4 you can see how a saprophyte known as bread mold gets food.

Observation 4 How does bread mold get food?

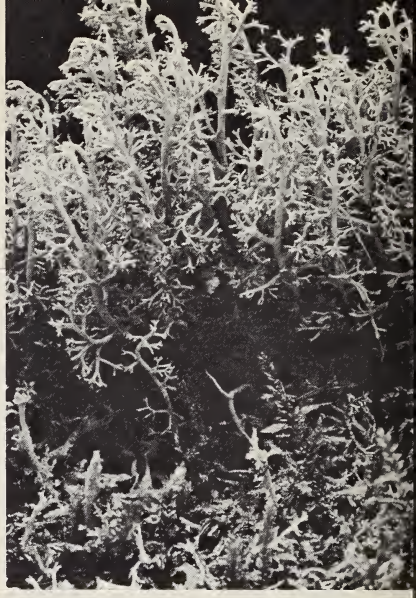
What you need: Water; blotting paper (or towel paper); dish (or jar) with tight cover; slice of fresh bread; dusty cloth.

What you do: Moisten the blotting paper or towel paper and fold it so as to fit over the bottom of the dish or jar. Lay the bread on the moist paper. Shake a dusty cloth over the bread. Then cover the dish or jar tightly and leave it in a warm place for several days. What happens?

Can you see a white, cottony mass growing over the bread? The bread mold sends hundreds of tiny threads down into the bread to soak up food. Where did this food come from? After a time, you will see black, yellow, or green material on the white mass. This colored material is made up of the many spores of the mold plants. The spores can grow into new mold plants.

Bread is made from flour, which is made from wheat seeds. The bread mold sends tiny threadlike tubes into the bread. These tubes give out chemicals that change the bread and make some of it dissolve. In other words, the chemicals digest the bread much as the juices in your body digest food. Then the dissolved food from the bread goes into the mold plant through the threadlike tubes in much the same way that water and dissolved minerals get into the root hairs of green plants.

On rocks, trees, or even fence posts, you may find patches of brown, black, red, gray, or green. Many of these patches are *lichens* (lī′kənz). For a long time, scientists thought that a lichen was a single plant. But when they looked at a lichen through a powerful microscope, they discovered that it was really made of two kinds of plants—a fungus and an alga. Living together, these two kinds of plants can grow where neither one could live alone.



Not all lichens are flat patches on fence posts or rocks. Some, like the one on the left, are leafy. Others grow as short stalks with tips branching like a deer's antlers.

The fungus soaks up what little water there is and keeps the alga from drying out. The alga can make food, because it contains chlorophyll. By sending its threadlike tubes into the alga, the fungus gets some of this food. So both kinds of plants are helped by their partnership.

SELF-TESTING EXERCISES

1 Why must there be green plants in every community of living things?

2 **a** State two ways in which animals get food.
b Name at least three kinds of animals that get food in each of these ways.

3 **a** Why are dodder and mistletoe considered to be parasites?
b How is a saprophyte different from a parasite?

4 **a** Which group of plants cannot make its own food? Why?
b How do plants that belong in this group get food?

5 How do lichens get food and water?

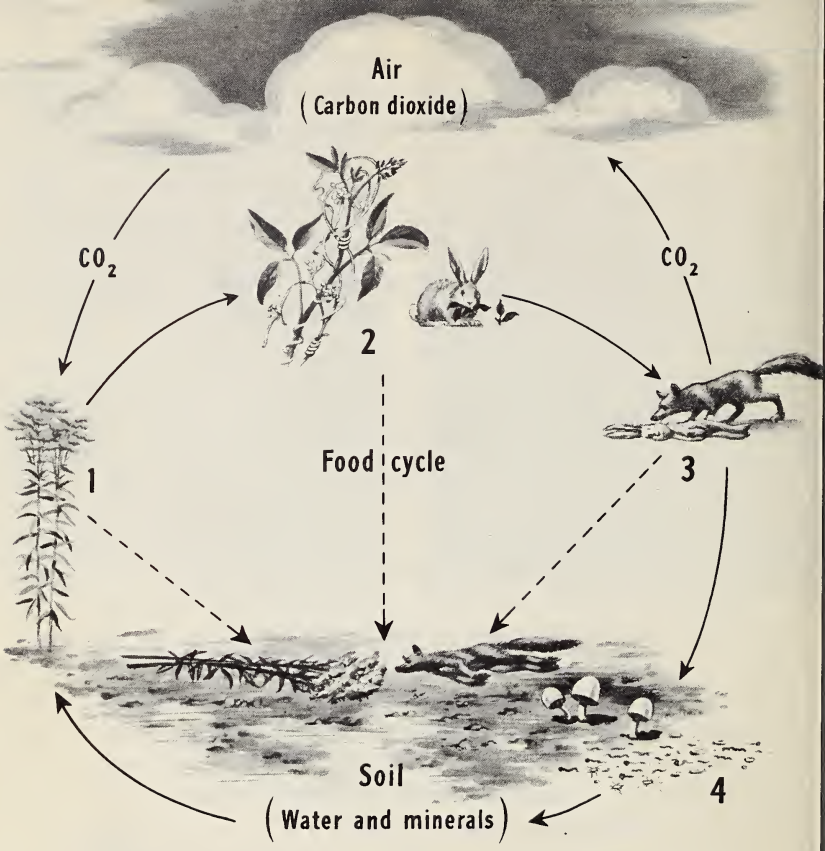
HOW ARE GREEN PLANTS KEPT SUPPLIED WITH MATERIALS? All the living things in every community depend on green plants for food. To make food, green plants take carbon dioxide, water, and minerals from the air and the soil. Some of this food is used to provide living things with energy. But much of this food is changed into other materials from which the bodies of living things are made. In this way, huge amounts of the elements and compounds in food become locked up in the bodies of plants and animals.

Because the earth is so big, you might suppose that the supply of carbon dioxide, water, and minerals could never run out. But that is not true. If these materials were not put back where they can be used over again, the supply of them would have been gone long ago. Without other groups of living things, green plants could not keep on making food. These other living things keep green plants supplied with materials from which food is made.

You can see what happens if you go into the woods. There you will find dead leaves, branches, and tree trunks lying on the ground. You may even find the dead bodies of animals such as rabbits, birds, and insects. All these dead things contain materials that were taken from the soil and the air. Look carefully at a fallen tree that has been dead for a long time. Some of its wood is now so soft that you can crush it into fine powder with your fingers. This wood has rotted, or decayed.

In Unit 5 you learned that rotting, or decay, is a chemical change. Scientists have discovered that this chemical change is brought about by the plants known as saprophytes. These bacteria, molds, and other fungi get their food from dead plants and animals or from materials that have come from living things. When anything decays, it decomposes into elements and compounds. Most of these materials go back into the soil. But some of them, such as carbon dioxide, go off into the air. In this way, materials locked up in the bodies of plants and animals are put back into the air and the soil. Then green plants can use these materials to make more food.

You have been reading about the *food cycle* that takes place in every community of living things. A cycle is a series of events that



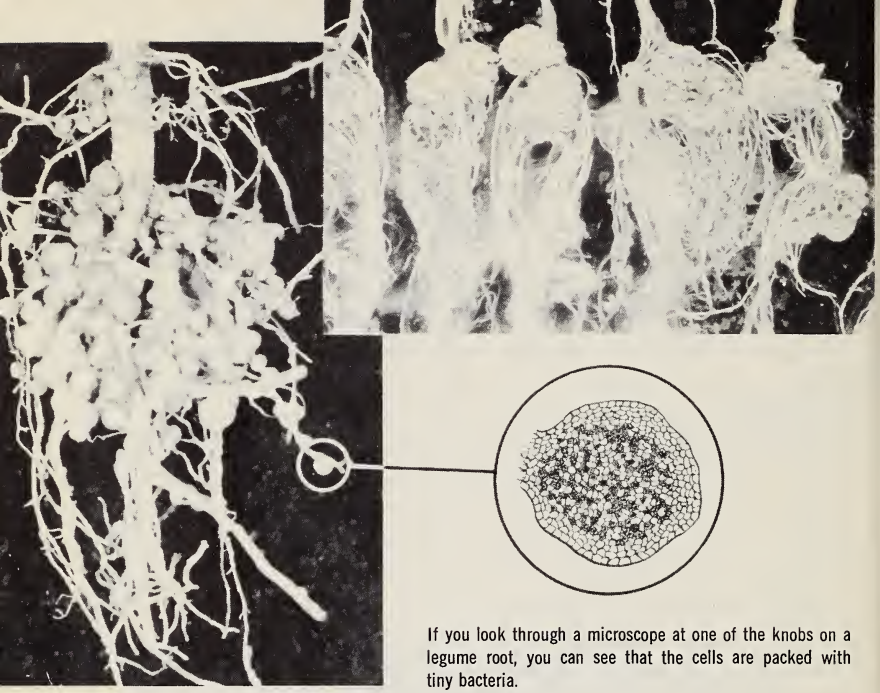
happen over and over again in the same order. The chart on this page shows some important facts about the food cycle. In every community of plants and animals, there are at least four different groups of living things. Each group has its place in the life of the community. The first group is made up of the green plants that make food from materials in the soil and the air. In the second group are the plants and animals that use green plants for food. The third group of living things feeds on the animals that eat green plants. In the fourth group are the bacteria, molds, and other fungi that get food from dead plants and animals and make them decay. As their dead bodies decompose, materials are put back into the soil and the air.

Of course, a community of plants and animals may have more than four different groups of living things. In some communities, a fifth group helps keep green plants supplied with nitrogen. You know that green plants must have this element to make proteins. Nearly four fifths of the air is nitrogen, but most plants cannot take nitrogen out of the air. They get the nitrogen that they need from certain minerals in the soil. These minerals are nitrogen compounds that will dissolve in water and then go into the roots.

As green plants make proteins, the supply of nitrogen compounds in the soil is slowly used up. However, some kinds of bacteria can take nitrogen out of the air in the soil and make nitrogen compounds that green plants can use. These bacteria often form a partnership with plants such as beans, peas, alfalfa, clover, and soybeans. Plants like these are called *legumes* (leg′ūmz). Working together, the bacteria and legumes can produce larger amounts of nitrogen compounds than the bacteria can alone.

From the soil some of the bacteria get into the roots of a legume. Then the bacteria cause little knobs to grow on the roots. In these little knobs, the bacteria take nitrogen out of the air in the soil and make nitrogen compounds. The legume uses the nitrogen compounds to make proteins, while the bacteria get water and a place to live from the legume. So this partnership helps both the legume and the bacteria. It also helps other green plants in the community, by adding to the supply of nitrogen compounds in the soil.

Many farmers use this partnership between bacteria and legumes to keep the soil rich in nitrogen compounds. Corn, cotton, and many other plants need much nitrogen. If these plants are grown in the same field year after year, they use up most of the nitrogen compounds in the soil. As a result, the crops get poorer each year. To keep this from happening, a farmer rotates his crops. Or as we say, he carries on crop rotation. First, he plants crops that take nitrogen from the soil. Then he plants clover, soybeans, or other legumes that add nitrogen to the soil. When the legumes are cut, their roots decay. The nitrogen compounds in the roots go back into the soil. Sometimes the whole plant is plowed under. When this is done, a large amount of nitrogen is added to the soil.



If you look through a microscope at one of the knobs on a legume root, you can see that the cells are packed with tiny bacteria.

SELF-TESTING EXERCISES

1 **a** What materials are green plants always taking out of the air and the soil?

b How are these materials put back where they can be used over again?

2 Explain what is meant by the food cycle in a community of living things.

3 **a** What four groups of living things are found in every community of plants and animals?

b What other group is found in some communities?

4 **a** Why do green plants need nitrogen?

b How do they get this element?

5 **a** How are both bacteria and legumes helped by their partnership?

b Why is this partnership important to farmers?

c Name at least four plants that are legumes.

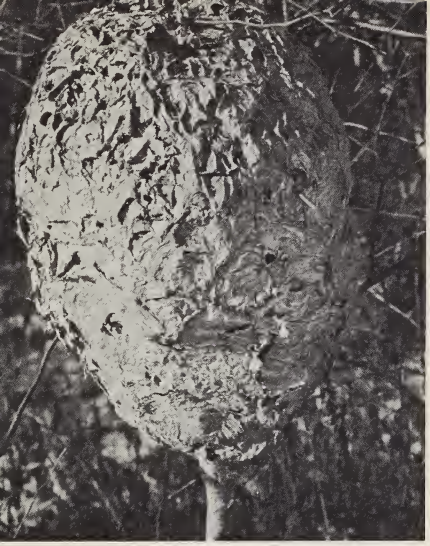
6 **a** What is meant by crop rotation?

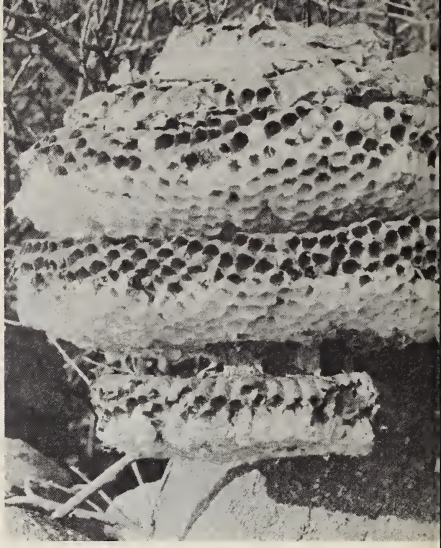
b Why do farmers rotate their crops?

HOW DO SOCIAL ANIMALS HELP EACH OTHER? Some kinds of animals live and work together for the good of all the others in the group. Such animals are known as social animals. By forming a group, they can live better than if each one lives alone. Cows, sheep, deer, elephants, wolves, prairie dogs, and many kinds of fish have a very simple social life. They merely feed or hunt together in groups.

Beavers have a much higher level of social life. They live in colonies in shallow lakes and streams. If the water in a stream is not deep enough, they build a dam across it. Some of these dams are as much as 1000 feet long. With their sharp teeth, beavers cut down trees for building materials. They use sticks, stones, and mud to build their dams and homes. The homes are hollow mounds built out in the water away from enemies. The beavers can get into their homes only through an opening under water. In these homes, they live and raise their young. Each beaver works for the good of the colony as well as for itself.

Beavers work together to cut down trees and build their dams and homes. The dam makes a quiet pond where the beavers can build large log houses.





Perhaps you have seen a wasp nest like this. It was made by the paper wasps. They work together to make the large nest containing hundreds of cells with walls of paperlike material.

Insects such as bees, ants, termites, and wasps have an even higher level of social life. You probably know that honeybees live together in colonies. There may be as many as 60,000 bees in one hive. Most of these bees are workers. Some of them gather material to make honey and other food. Others make wax for the combs in which the food is stored. Still others keep the hive clean or take care of the young. Some workers even guard the hive to keep out wasps and other enemies. A few bees in the hive are males known as drones. They do no work, but a drone is the father of a new colony. Besides the workers and the drones, there is one other bee in the hive. This is the female, or queen, that lays all the eggs. She is the largest bee and the mother of the colony. Without her, the colony would soon die out because the workers live only about six weeks.

Ants also live in large colonies. Sometimes a single nest contains thousands of these insects. The nest may be in the ground, in dead wood, or in plant stems. Most of the ants are workers. But there are also males that do no work and females, or queens, that lay the eggs. A colony of ants usually has several queens instead of just one as in a colony of bees. An ant queen spends almost her

In the cells of the nest, the young wasps are hatched. When they grow a little larger, they will join in the work of paper making.

whole life in the nest, laying eggs. Workers carefully tend the young until they are full-grown workers, too. After many eggs develop into workers, some of the eggs grow into males and females with wings. When these ants with wings are full grown, they leave the nest and fly away to start new colonies.

One kind of ant captures many small insects known as plant lice, or aphids. Worker ants protect the aphids and carry them to plants where they can get food. The aphids also help the ants. When the ants stroke the bodies of these insects, the aphids give off a sweet liquid. Then the ants drink the liquid. So you can see why aphids are sometimes called ant cows. Some ants even capture other ants and make them slaves. If possible, the ants are captured while they are too young to move about. The helpless ants are carried back to the nest and cared for until they are full grown. Then they do all the work as slaves.

Another kind of ant is called the honey ant. Some of the workers cling to the roof of their underground nest and act as storage tanks for honey that other workers have gathered. Honey is stored in their abdomens, which become very large and rounded. When other ants in the colony need food, they stroke the ab-

Carpenter ants work together to cut tunnels in dead tree trunks. On the right, a worker ant guards a herd of aphids, or ant cows.

domens of the storage ants. Then they eat the honey that is given off. Leaf-cutting ants grow food in their underground homes. Some of the workers cut pieces from leaves and carry them into the nest. Other workers make the pieces of leaves into balls. On these balls a tiny fungus grows, and the ants use this plant for food.

Termites are often called white ants, but they are not really ants at all. They belong to a different group of insects. However, termites are social animals. In a colony of termites, there are workers, males, and queens. Some of the workers are much larger than the others. They act as soldiers and protect the colony. In many parts of our country, termites are pests. They get into buildings and eat away the wood. Sometimes buildings fall in after termites have weakened them in this way. Termites cannot digest the wood that they eat. They depend on other animals to do it for them. Inside their abdomens are many protozoans. These tiny one-celled animals change the wood into materials that the termites can use for food. In the warmer parts of the earth, termites build huge mounds of soil for their nests. Some of these nests are so strongly built that only explosives will break them apart.

SELF-TESTING EXERCISES

1 **a** What is meant by a social animal? Give several examples.
b Why can social animals live better than one animal can live by itself?
2 Explain why it is an advantage for a beaver to live in a colony rather than by itself.
3 Give several examples to show that a bee or an ant works for the colony rather than just for itself.
4 How do termites get food from wood that they eat?

PROBLEMS TO SOLVE

1 Refer to the chart of the food cycle on page 350. State at least six facts shown in the chart.
2 Choose some material that a green plant uses to make food. Then tell how the material passes through the food cycle until it is back in the soil or the air again.
3 What will happen to a dodder plant if it grows where it cannot touch a green plant? Explain your answer.
4 Why do farmers try to get rid of dodder in their clover fields?
5 Suppose that it does not rain for a month or two. How will the lack of moisture affect a community of plants and animals?
6 **a** How is the social life of beavers like that of ants?
b How are their social lives different?
c Why do we say that ants have a higher level of social life?
7 A community of plants and animals that includes bacteria which can make nitrogen compounds is more likely to be successful than a community without these bacteria. Why?
8 **a** How are the ways in which bees live and work together like the ways in which people live and work together?
b How are these ways different?
9 **a** Why is it an advantage for ants to have wings when they leave the nest to start a new colony?
b Why is it an advantage for ants that stay in the nest not to have wings?
10 When individuals live in a group, are they more independent or less independent than an individual that lives alone? Explain your answer.

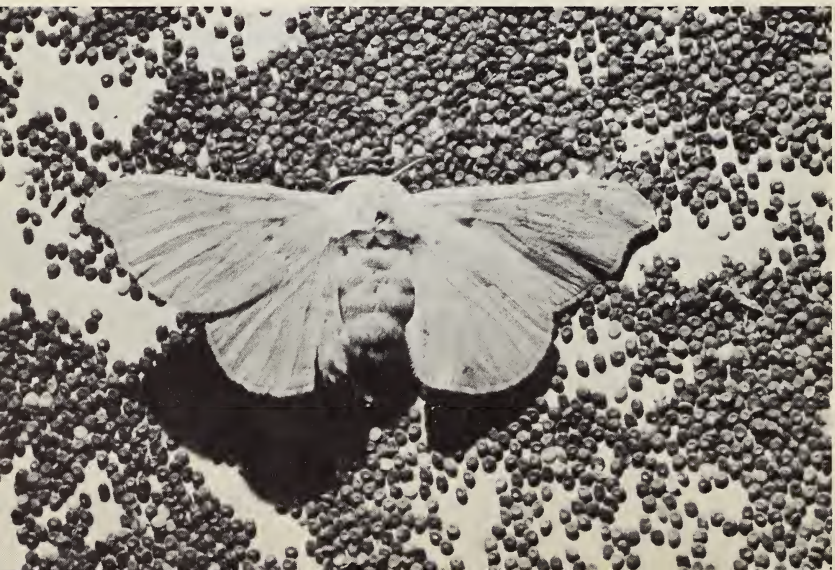
3

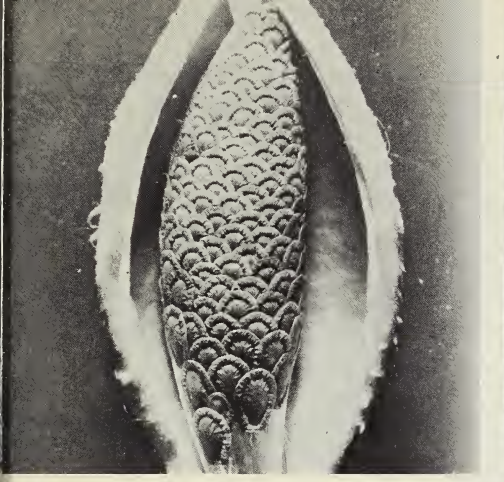
How do living things keep a balance of numbers?

WHY IS THERE A STRUGGLE FOR EXISTENCE? In every community of living things, each plant or animal does something useful for all the others. But living things not only help each other. They harm each other, too. They need food, air, water, light, and a place to live. So they are always competing with each other in the struggle to stay alive.

Every year, billions of new animals and plants are produced. A female codfish lays as many as 9 million eggs a year. About half of these become males and about half females. If all the females lived and produced young, at the end of the second year there would be 40,500,000,000,000 codfish. By the end of the third year there would be 4½ million times as many codfish as there were at the end of the second year. The ocean would soon be so full of codfish that there would be no room for water. In ten years every pair of sparrows would be the parents and grandparents of 275,716,986,698 birds. And if all the eggs laid by one female mosquito lived and produced young, in three months there would be 102,914,592,864,480,008,004,001 mosquitoes from this one female alone.

One silkworm moth may lay as many as 500 eggs. Each of these could grow into another moth in two months.





Each milkweed pod sheds hundreds of these feathery seeds, and there may be many pods on each milkweed plant. Why is the earth not overrun with milkweed plants?

Plants can also reproduce very rapidly. A scientist once counted 357 plants that grew from seeds on 6 square feet of soil. He estimated that if all of these plants and their offspring each produced ten good seeds, 3½ billion plants would be produced in the tenth year. These plants would need over 35,000 square miles in which to grow. Some bacteria divide in two in less than half an hour. In one week the offspring of just one of these bacteria would fill the ocean. And in one more day they would produce a mass of protoplasm several times bigger than the earth!

Now you can understand why there is a very real struggle for existence. More living things are produced each year than can possibly grow up. There is not enough food, air, water, and light for all of them. Nor is there room enough for all of them to grow. Each animal or plant must get what it needs to stay alive. The strongest animals and plants, or those that work together best, live. The weakest animals and plants, or those that do not work together, die.

SELF-TESTING EXERCISES

1 What things do animals and plants need to stay alive?

2 Explain why there is a struggle for existence.

HOW DO LIVING THINGS REACH A BALANCE? If all the animals and plants lived and produced young, the earth would soon be overrun with living things. Of course, that does not happen. Animals and plants have a hard time staying alive. In fact, most of them never live long enough to become full grown and produce young. So the number of each kind of living thing in a community stays about the same year after year.

A female frog lays hundreds of eggs each year. Many of the eggs are eaten by fish. The eggs that hatch grow into tadpoles. But many of the tadpoles are eaten by leeches, water bugs, fish, and birds. Other tadpoles may be killed by cold, heat, dry weather, or lack of food. Only a few tadpoles ever develop into frogs. Most of these young frogs are eaten by birds, fish, turtles, and snakes. Out of the hundreds of eggs laid by a female frog, very few ever become full-grown frogs that can produce young. And so the number of frogs in a pond stays about the same year after year.

It is just as hard for seeds to develop into full-grown plants. Even before the seeds fall from a plant, many of them are eaten by birds and other animals. Only the seeds that fall to the ground have a chance to grow. But many of these fall on top of the soil and are eaten by birds. Others are covered with soil and eaten by animals that live in the earth. Still other seeds are blown into the water or some other place where they cannot grow. So only a few seeds from any plant ever get a good chance to develop into new plants.

Before seeds will grow, they must be moist and warm. Dry or freezing weather kills many of them just as they are beginning to grow. After the seeds start growing, the young plants must have enough water and minerals from the soil as well as light from the sun. Fast-growing plants quickly send their roots down into the soil. Very soon they are taking in water and minerals. These plants send their stems and leaves up rapidly. But slow-growing plants get a later start. When their leaves and stems develop, they may be overshadowed by the faster growing plants. So the slower growing plants may die from lack of light.

Many plants that win in the struggle for water, minerals, and light lose their lives when animals use them for food. Others are killed by parasites. Out of all the seeds made by a plant, very few

This barn owl has five young owls to feed, and each one can swallow a rat in one gulp. You can see how one barn-owl family helped keep down the number of rats and how busy this owl must have been every night.

ever become full-grown plants that can produce more seeds. And so the number of seed plants in a field or woods stays about the same year after year.

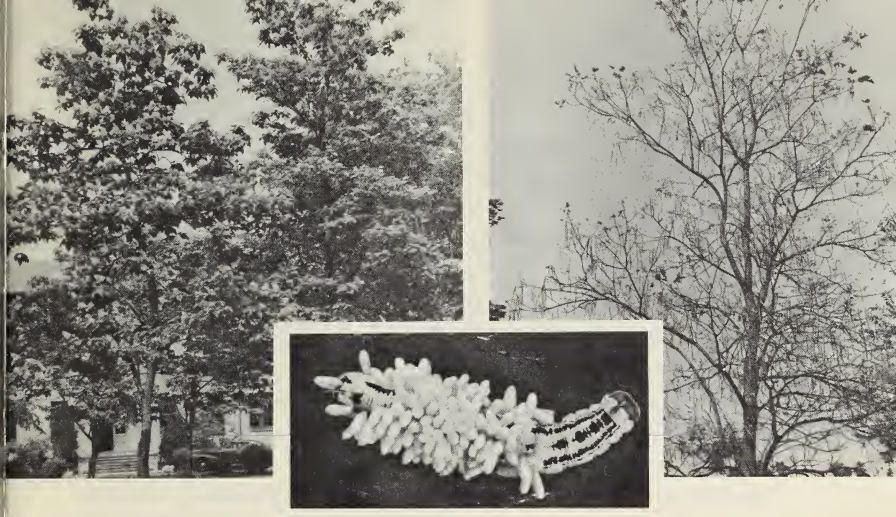
The struggle for existence keeps down the number of animals and plants that become full grown. Out of this struggle comes a balance of numbers among the different kinds of living things in a community. In other words, just enough young animals and plants grow up to take the place of the old ones that die or are killed. An example will show you how the living things in a community reach a balance of numbers.

Suppose that some kind of insect produces an unusually large number of young. There will be food for a larger number of birds that feed on these insects. So the number of birds will increase. As the number of birds increases, more and more of the insects will be eaten. As the insects get fewer and fewer, there will be less food for the birds. So the number of birds will decrease. Before long, both the insects and the birds will be back to their usual numbers. In other words, there will again be a balance of numbers between the insects and the birds in the community.

A plague of grasshoppers has come to this town. The grasshoppers are swept up in big piles like leaves in autumn.

Of course, this is a very simple example of what may happen. Yet it shows how living things reach a balance of numbers. An increase in the number of animals or plants causes an increase in the number of living things that use them for food. Then there will be fewer of these animals or plants to produce young. Soon there will be less food for the other living things, and the number of these living things will decrease. In this way, the balance of numbers is restored.

Sometimes the balance of numbers is seriously upset. A certain kind of animal suddenly produces a huge number of young, and they spread far and wide. There have been many plagues of grasshoppers in our country. Millions of these insects swarm over the land and destroy almost every green plant in their path. The grasshoppers are not kept down to their usual number by birds and other animals that use them for food. There are not enough of these animals to eat all the grasshoppers that are produced. Usually a plague of animals does not stop until they have used up all the food. But bad weather or even disease may kill many of the animals and help bring them down to their usual number.



The wormlike larvae of a certain moth feed on the leaves of catalpa trees. A kind of fly lays its eggs on the larvae. When the eggs hatch, they feed on the moth larvae and soon kill them. What does keeping the balance of numbers of these insects have to do with the difference between the catalpa trees in the pictures?

SELF-TESTING EXERCISES

1 Why is the earth not overrun with living things?
2 Explain why most of the eggs laid by a female frog never become full-grown frogs.
3 What may keep a seed from becoming a full-grown plant? Mention as many different things as you can.
4 What is meant by a balance of numbers among living things?
5 **a** How does the number of insects affect the number of birds?
b How does the number of birds affect the number of insects?
c Explain how insects and birds reach a balance of numbers.
6 How is a balance of numbers restored when there is a plague of animals? Mention several ways.

HOW DO PEOPLE UPSET THE BALANCE OF NUMBERS? In a community of living things, the struggle for existence results in a balance of numbers. The kinds of animals and plants that live in the community are fitted to the climate, soil, and other conditions. Year after year, there are about the same numbers of the same

kinds of living things. Some kind of animal or plant may upset the balance now and then. But over a long period of time, the numbers of living things in the community are kept in balance.

Now suppose that people move into a region where certain kinds of animals and plants have been living together for hundreds or even thousands of years. Trees are cut down in the forests. Grasslands are plowed up and sowed with crops. Plants that people do not want are destroyed. Squirrels, rabbits, mice, birds, snakes, and many other animals are killed. New kinds of plants and animals are brought in. Before long, the balance of numbers is completely upset. The new conditions that people provide may be helpful to some kinds of living things. These kinds will live and reproduce in larger numbers. But the new conditions may be harmful to other kinds of living things. These kinds will be reduced in number until they finally disappear or nearly disappear.

Here is what actually happened when a balance of numbers was disturbed. There were no rabbits in Australia until about 100 years ago. Then a man brought a few into the country from England. He hoped that they would multiply rapidly enough to provide some hunting on his farm. They did! The rabbits had no enemies in Australia. There were no foxes or owls to hold them in check. So their numbers increased very fast. Soon the rabbits were pests. They ate up grass, vegetables, and even small trees. They did so much damage that the government offered a reward of $125,000 for a plan to get rid of them. Many different plans have been tried, but so far no one has earned the reward. Rabbits are still pests in Australia. Something like this has happened in many other places. An animal or plant taken to a new country upsets the balance of numbers and becomes a pest.

People have disturbed the balance in many other ways. The tough roots of grass hold moisture and keep the soil from being blown away. When the grasslands in the western part of our country were plowed up, dust storms swept away much of the soil. Trees keep rain from washing away soil. Cutting down the forests has resulted in terrible floods. Insect poisons such as DDT kill flies, mosquitoes, and other insect pests. Unfortunately, these insect poisons also kill bees and other helpful insects. If too many

By fencing in waterholes where the rabbits come to drink, many of the rabbits in Australia can be caught and used. But there are still millions left.

insects are killed with poisons, birds that eat insects may die from lack of food. The same thing may happen to frogs, toads, and fish.

From what you have been reading, you can see why we need to conserve the living things in our communities. Any change that we make in the earth and its living things may have far-reaching effects. We cannot always tell ahead of time just what these effects will be. So we must be careful when we disturb the balance of living things in our communities. If we disturb it too much, we may cause ourselves serious harm.

SELF-TESTING EXERCISES

1 How do people disturb the balance of living things? Mention as many different ways as you can.

2 Give at least two examples to show that people can harm themselves by making changes in the earth and its living things.

3 Why did rabbits become pests in Australia?

PROBLEMS TO SOLVE

1 Do you think that social animals have an advantage over other animals in the struggle for existence? Give reasons for your answer.

2 One oyster can produce 80 million eggs a year. Why are there not more oysters along the seacoasts?

3 Explain why an animal or plant that is useful in one country may become a pest in another country.

4 Would you expect to find a balance of numbers in a region where people have never been? Give reasons for your answer.

5 a When too many plants start growing, how is a balance of numbers restored?

b When too few plants grow, how is a balance of numbers restored?

6 There were many deer in a forest. Hunters killed the mountain lions, wolves, and other enemies of the deer. What changes do you think took place because of what the hunters did?

7 How do you think a farm would change if no one took care of it for 100 years? Explain your answer.

8 Few plants grow on the ground under the trees in a dense forest. Why?

9 When roads are built into the wilderness, the number of fish in the streams and lakes often decreases. How can you explain this?

10 a Make a list of the ways in which animals and plants help each other.

b Make another list of the ways in which animals and plants harm each other.

SUMMARY EXERCISES

1 Make a list of the big ideas that you learned in this unit. Be sure to write them as complete sentences.

2 Show that you understand what the following words mean: taproot, fibrous roots, epidermis, stomate, guard cells, photosynthesis, saprophyte, lichen, food cycle, legume.

ADDITIONAL ACTIVITIES

1 Find out what plants and animals provide our most important foods. Then make a report to your class. Collect pictures of these plants and animals and prepare a chart to illustrate your report.

2 Grow two potted plants from seeds. Keep one plant in the dark and the other in the sunlight. Which plant has more chlorophyll? What does this show about chlorophyll in leaves?

3 Just after a period of damp, warm weather, look for mushrooms. How do they get food? What do they use for food?

4 If a microscope is available, look at a piece of epidermis peeled from a geranium or onion leaf. Find the stomates and guard cells.

5 Look at different kinds of green plants to see how their leaves are placed to catch sunlight. What do you discover?

6 Some plants such as Venus's-flytrap, the sundew, and the pitcher plant use animals for food. Find out how these plants capture animals.

7 Ask a farmer what plan he uses in rotating his crops. Then report what you learn to your class.

8 Build an ant nest and put a colony of ants in it. If you can, get a queen so that there will be eggs for the colony. After the ants become used to their new home, watch them to see how they live and work together.

9 Carefully dig up a legume such as a clover, alfalfa, or soybean plant. Wash away the soil clinging to the roots. Then look for the little knobs containing bacteria that make nitrogen compounds.

10 Make prints of different kinds of leaves. Spread a thin layer of green or black printer's ink on a sheet of glass. Lay the underside of a leaf on the ink and cover the leaf with a sheet of scrap paper. Run a small roller back and forth over the paper. Then remove the paper. With a pair of tweezers pick up the leaf and lay the inked side on a clean sheet of white paper. Cover the leaf with a clean sheet of scrap paper and run the roller over it as before. When you remove the scrap paper and leaf, you should have a good print of the veins of the leaf. Label your leaf prints and mount them on a chart.

11 In reference books, read about the following topics: photosynthesis; decay; nitrogen-fixing bacteria; earthworms; parasitism; ecology; diseases of plants; weeds; carnivorous, herbivorous, and omnivorous animals; social animals.

Science words

Here is a list of the important science words in this book, with the pronunciation and the meaning of each one. The marked letters in parentheses are sounded according to the letters in the following list of sample words. The accented syllable is marked ′. This lighter mark ′ shows a lighter accent.

a hat, cap	ėr term, learn	oi oil, voice
ā age, face	i it, pin	ou house, out
ã care, air	ī ice, five	u cup, butter
ä father, far	o hot, rock	u̇ full, put
e let, best	ō open, go	ü rule, move
ē equal, see	ô order, all	ū use, music

ə represents *a* in about, *e* in taken, *i* in pencil, *o* in lemon, *u* in circus.

al ga, plural **al gae** (al′gə, al′jē), all-body plant that contains chlorophyll and can make its own food.

al ka li (al′kə lī), material that turns red litmus paper blue. Alkalis have a bitter taste. They are also called bases.

al loy (al′oi or ə loi′), metal made by melting together two or more metals, or a metal and some other material.

an a lyt i cal (an′ə lit′i kəl) **balance,** delicate pair of scales for weighing things.

an a lyze (an′ə līz), examine and separate (a material) into parts. A chemist analyzes a compound to find out what elements and how much of each element there is in it.

an thra cite (an′thrə sīt) **coal,** hard coal. It burns with a small flame and gives very little smoke.

ap pend age (ə pen′dij), part that extends out from the body of an animal.

a rach nid (ə rak′nid), arthropod with eight legs and two distinct body divisions. Spiders, ticks, and scorpions are arachnids.

ar thro pod (är′thrə pod), invertebrate animal with jointed legs. Insects, crustaceans, arachnids, and many-legged animals are arthropods.

as tron o mer (əs tron′ə mər), scientist who studies the earth's relations to the sun, moon, stars, and other heavenly bodies.

at om (at′əm), the smallest particle of an element that can exist.

a tom ic (ə tom′ik) **energy,** form of energy stored in all materials.

at tract (ə trakt′), pull toward itself.

base (bās), material that turns red litmus paper blue. Bases have a bitter taste. They are also called alkalis.

bi ol o gist (bī ol′ə jist), scientist who studies living things.

bi tu mi nous (bi tū′mi nəs or bi tü′mi nəs) **coal**, soft coal. When not completely burned, it makes a great deal of smoke.

cal o rie (kal′ə ri), amount of heat needed to raise the temperature of one pound of water about 4° F.

Cen ti grade (sen′ti grād), the scale on a thermometer that has 0° for the temperature at which water freezes and 100° for the temperature at which water boils.

chem i cal a nal y sis (kem′i kəl ə nal′i sis), test that shows what elements and compounds a material contains and how much of each element and compound there is in the material.

chem ist (kem′ist), scientist who works on problems about materials.

chi tin (kī′tin), the hard, horny material contained in the skins of arthropods.

clas si fy (klas′i fī), put together in a group (things) that are alike in some ways. Scientists classify living things into two groups: animals and plants.

clin i cal (klin′i kəl) **thermometer,** instrument used to measure the temperature of the body.

com bi na tion (kom′bi nā′shən), the chemical change in which two or more elements combine to form a new compound.

com bus tion (kəm bus′chən), rapid oxidation, or burning.

con dense (kən dens′), change from a gas to a liquid.

con serve (kən sėrv′), use (materials) wisely.

con tract (kən trakt′), get smaller.

cos mic (koz′mik) **rays,** extremely powerful rays somewhat like X rays.

crus ta cean (krus tā′shən), crusted animal; one of the groups of arthropods. Crabs, lobsters, and shrimps are crustaceans.

de com pose (dē′kəm pōz′), separate into what it is made of.

de com po si tion (dē′kom pə zish′ən), the chemical change in which a compound separates into other compounds or into the elements that compose it.

de fi cien cy (di fish′ən si) **disease,** disease caused by the lack of a certain material, usually a vitamin or mineral.

di a phragm (dī′ə fram), large sheet of muscles in a mammal, separating the chest, or thorax, from the abdomen.

di et (dī′ət), variety of foods usually eaten by a person.

di ges tion (di jes′chən), the process of dissolving and changing food chemically so that it can be used by the body.

dip ping nee dle (dip′ing nē′dəl), special kind of compass in which the needle points up and down.

dis till (dis til′), change (a liquid) into a gas and then condense it.

e lec tron (i lek′tron), particle of electricity.

ep i der mis (ep′i dėr′mis), the outer layer of cells in a leaf.

e qua tion (ē kwā′zhən), an expression using symbols and formulas to show what happens during a chemical change.

e vap o rate (i vap′ə rāt), change from a liquid to a gas.

ex pand (eks pand′), get larger.

Fahr en heit (far′ən hīt), the scale on a thermometer that has 32° for the temperature at which water freezes and 212° for the temperature at which water boils.

fi brous (fī′brəs) **roots,** roots of about the same size. Plants like corn, rye, and wheat have fibrous roots.

field of force (fēld əv fōrs), space around a magnet where its force acts; magnetic field.

food cy cle (füd sī′kəl), series of events in which materials locked up in the bodies of animals and plants are put back into the air and the soil. Then green plants can use these materials to make more food.

for mu la (fôr′mū lə), abbreviation showing with symbols the elements and amount of each element in a compound.

for ti fy (for′ti fī), improve by adding vitamin A.

ge ol o gist (ji ol′ə jist), scientist who solves problems about the earth's surface and what is under it.

goi ter (goi′tər), disease in which the thyroid gland in the front of the neck becomes much enlarged.

guard cell (gärd sel), one of a pair of cells around each stomate in a leaf. Guard cells control the amount of water that evaporates.

in sol u ble (in sol′ū bəl), not able to be dissolved. Some materials are insoluble in water.

in ver te brate (in vėr′ti brāt), 1. without a backbone. 2. animal without a backbone.

leg ume (leg′ūm), one of a group of certain plants that form a partnership with bacteria to take nitrogen from the air in the soil. Peas, beans, alfalfa, and clover are legumes.

li chen (lī′kən), alga and fungus growing together.

lines of force (līnz əv fôrs), pattern of lines around which the force of a magnet seems to act.

mag net ic field (mag net′ik fēld), space around a magnet where its force acts; field of force.

mag net ite (mag′ni tīt), a kind of iron ore that attracts iron and steel as a magnet does.

mat ter (mat′ər), anything that takes up space and has weight. All materials are matter.

me te or ol o gist (mē′ti ər ol′ə jist), scientist who studies changes in the weather on the earth.

mo lec u lar the o ry (mə lek′ū lər thē′ə ri), belief of scientists that all matter is made up of tiny particles called molecules.

mol e cule (mol′i kūl), smallest particle into which a material can be divided without chemical change. The molecule of an element is made of one or more atoms of the same kind. The molecule of a compound is made of two or more kinds of atoms.

mol lusk (mol′əsk), invertebrate animal having a soft body not made of segments. Snails, oysters, and clams are mollusks.

neu tral (nū′trəl), neither acid nor base. Salts are neutral.

neu tral ize (nū′trəl īz), act on to make neutral. Acids and bases neutralize each other and form a salt.

nu cle us (nū′kli əs), rounded, heavier piece of protoplasm inside almost all cells. Without its nucleus, a cell cannot live long.

or gan (ôr′gən), one of the main parts of an animal or plant. Each organ does certain work for the animal or plant.

ox i da tion (ok′si dā′shən), the chemical change in which oxygen combines with another element.

ox i dize (ok′si dīz), combine with oxygen.

par a site (par′ə sīt), an animal or plant that lives in or on the body of another living thing from which it gets its food.

pel la gra (pə lā′grə or pə lag′rə), a deficiency disease caused by lack of a B vitamin in the diet.

pho to syn the sis (fō′tō sin′thi sis), the chemical change by which green plants make carbohydrates from carbon dioxide and water with the help of chlorophyll and sunlight.

phys i cist (fiz′i sist), scientist who studies problems about force and energy.

pre dict (pri dikt′), tell what one thinks will happen before it happens.

prin ci ple of sci ence (prin′si pəl əv sī′əns), statement that tells what usually happens under certain conditions.

prop er ty (prop′ər ti), a characteristic of a material. A material has both physical and chemical properties.

pro to plasm (prō′tə plazm), a clear material somewhat like the white of an egg. The living, active part of every cell is protoplasm, which is made almost entirely of proteins and water.

pro to zo an (prō′tə zō′ən), tiny, one-celled animal.

re pel (ri pel′), push away from itself.

re place (ri plās′), change places with.

re place ment (ri plās′mənt), the chemical change in which an element from one compound changes places with an element from another compound.

re search (ri sėrch′ or rē′sėrch), search for facts about the conditions, materials, forces, and living things in our world.

re sponse (ri spons′), way in which an animal or plant acts when it receives a stimulus.

re store (ri stōr′), enrich (foods) with B vitamins and iron.

salt (sôlt), material formed when an acid and a base act on each other. Sodium chloride, or table salt, is only one kind of chemical salt.

sap ro phyte (sap′rō fīt), plant that gets its food from dead things or from materials that have come from living things.

seg ment (seg′mənt), section of the body of some arthropods and worms.

sol u ble (sol′ū bəl), able to be dissolved. Sugar is soluble in water.

so lu tion (sə lü′shən or sə lū′shən), mixture formed by dissolving one material in another.

sol vent (sol′vənt), material that can dissolve other materials. Water, alcohol, and carbon tetrachloride are solvents.

spec tro scope (spek′trə skōp), extremely sensitive scientific instrument used by astronomers and chemists.

spon ta ne ous com bus tion (spon tā′ni əs kəm bus′chən), the bursting into flame of materials that have combined with oxygen and become hot enough to burn.

state of mat ter (stāt əv mat′ər), form that matter can have. The three states of matter are solids, liquids, and gases.

steth o scope (steth′ə skōp), instrument used by a doctor to examine the heart and lungs.

still (stil), apparatus for distilling water and other liquids.

stim u lus, plural **stim u li** (stim′ū ləs, stim′ū lī), message received by a living thing from its surroundings.

sto mate (stō′māt), tiny opening in the epidermis of a leaf.

sus pend ed (səs pen′did), spread throughout a liquid but not dissolved.

sus pen sion (səs pen′shən), mixture in which small particles of a solid remain spread throughout a liquid without dissolving.

sym bol (sim′bəl), abbreviation of one or two letters that stands for the name of an element.

tap root (tap′rüt), large, main root of a plant.

the o ry (thē′ə ri), explanation that seems to be true but is not absolutely certain.

thy roid gland (thī′roid gland), gland in the front of the neck.

tri chi na (tri kī′nə), a roundworm that usually gets into the body in raw or poorly cooked meat and can cause a serious disease.

ul tra vi o let rays (ul′trə vī′ə lit rāz), invisible rays from the sun that help make vitamin D in the body.

va por ize (vā′pər īz), change to a gas, or vapor.

ver i fy (ver′i fī), prove to be true by testing in different ways.

ver te bra, plural **ver te brae** (vėr′ti brə, vėr′ti brē), each bone in the backbone, or spine.

ver te brate (vėr′ti brāt), 1. with a backbone. 2. animal with a backbone.

vol ume (vol′ūm), amount of space that a material takes up.

X rays (eks′rāz), invisible rays used to examine bones and other things inside the body.

ze ro-de gree line (zēr′ō di grē′ līn), line along which a compass needle always points true north; line of no variation.

Index

* after a page number indicates a picture on that page.

Abdomen, 38, 45, 46
Acid, 158; acetic, 91, 157; test for, 157; citric, 157, 165; nitric, 162*; sulphuric, 163*, 211; hydrochloric, 174*, 281, 303; ascorbic, 309
Acorn, 268*
Air, characteristics of, 80-84*, 86*-87*; mixture of gases, 86, 153, 264; nitrogen in, 86, 153, 264, 351; oxygen in, 86, 153, 167, 205, 264; in water, 92; molecules in, 97*, 103*; effect of heating on, 111*; water in, 120, 127-128; liquid, 129, 131-132; and rust, 165; needed in fire, 196-197; regulating in fire, 198-202; used to make electric current, 219; non-living thing, 262; in soil, 329*, 351; space in leaf, 338*; materials returned to, 350*
Alcohol, 91, 93, 111, 123; yeast in, 65; evaporation of, 121; boiling point of, 124; freezing point of, 131; as fuel, 188*, 219
Algae, 63, 64*, 65, 268, 280*, 326*, 347-348*
Alkali, 158
All-body plants, 63, 64*-66
Alloy, 228-229, 237, 238
Alnico, 229*, 237, 255*
Aluminum, 119, 149*, 155, 237, 281*
Ammonia, fountain, 101*; gas, 101*; water, 158
Amoeba, 265, 271
Amphibians, 38, 40*-42, 72
Analytical balance, 27, 28*
Animals, diseases of, 17*; community of, 32*-33*, 328-330, 358, 360-362; classification of, 34-55, 262; with backbones, 36-42; reproduction of, 38-39, 41-42, 55, 265, 268, 358-359; water, 38, 41, 42, 47, 48, 52-55; warm-blooded, 38, 39; cold-blooded, 39, 40, 42; growth of, 41, 265; without backbones, 43-55; parasites, 49*, 51-52, 54*; likeness to plants, 52, 272*, 277*, 279*; one-celled, 54-55, 271, 272; meat-eating, 72-73, 346; flying, 74*; chemical changes in, 145; activities of, 260*-261*, 263, 264*, 265*, 266, 269, 277*; organs in, 270, 272; cells in, 271, 272*-274; elements in, 277-279*, 280*; compounds in, 280*-282; water in, 280-282; fats from, 301*; diet of, 308*-309*; food for, 326*-327*, 328, 345-346; struggle for existence among, 326*-327*, 329, 358-361; and plants dependent on each other, 329*, 345-350*, 351-356; plant-eating, 345-346; decay of, 349, 350*; social, 353*, 354*, 355*, 356*; balance of numbers of, 358*, 361*, 362*, 363*, 365*; plagues of, 362
Ant, 44*, 46, 266*, 354-356*
Antennae, 46, 47
Antifreeze, 111, 131
Aphid, 355, 356*
Appendage, 44-47, 49, 53
Arachnids, 44*, 45, 46-47
Aristotle, 6-7
Artedi, Peter, 71
Arthropods, 44*, 45*, 46*, 47, 69*, 74*
Asbestos, 146*, 156
Ash, fuel, 145, 186, 188, 205; from food, 303
Astronomers, 12*, 13, 29
Atomic energy, 14, 216, 220
Atomic theory, 171
Atoms, 96*, 171-172, 174

Backbone, 35-36
Bacteria, 26, 55, 64*-66, 271, 351-352*, 359
Baking powder, 112*, 165, 167
Baking soda, 165, 167, 211
Balance of numbers, 363*-365*
Balloons, weather, 13*; helium in, 29
Barnacles, 45*, 47
Base, 158
Basic seven, 313*, 314, 316*, 317*, 323*
Bat, 38, 39, 74*
Bean, 59, 270, 351
Beaver, 353*
Bee, 44, 46, 354
Beetle, 44*, 46
Beggar's-lice or **beggar's-ticks,** 70
Beriberi, 307, 310
Biologists, 15, 16*, 17*, 27, 35, 63, 70
Birds, structure of, 34-35, 37*-39, 68, 72, 74*; migration of, 39; food of, 345, 360-361, 365
Blood, cells in, 272*, 274; water in, 280, 305; carrier of food and oxygen, 294-296*; clotting of, 303; iron and copper in, 303
Blueprint, 168-169*
Body, chemical changes in, 145; elements and compounds in, 147*, 278-279; food for, 291-311; temperature, 296; minerals in, 303-305; water needed by, 305; builds, 320*-322
Boiling point, 116*, 123*, 124, 129, 131, 191
Bones, of vertebrates, 36, 39; food changed into, 145; calcium and phosphorus in, 158, 279, 281, 303, 314; cells in, 272*-273; repair of, 292; and rickets, 308
Brain, cells in, 274
Bread, yeast in, 65; enriched, 315; mold, 347
Breathing, 36, 38, 39, 41, 42, 46
Brittle star, 52
Bud, of yeast plant, 65, 268

Burning, as chemical change, 144-145, 167, 182-185; meaning of, 182-187; oxygen needed for, 182-185, 198, 218; heat and light from, 182-185, 188; of candle, 184-186*, 196; of fuels, 186-187; smoke from, 186, 188, 190, 197, 218; requirements for, 198
Butterfly, 35*, 44*, 46, 74*

Cactus, 56*, 260*-261*
Calcium, in body, 147, 158, 279*, 303, 314; test for, 156; carbonate, 172; in coral, 280*; on earth's surface, 281; phosphate, 281; in foods, 304, 314-315
Calorie, 317-321
Candle, 131; burning of, 184-186*, 196
Carbohydrates, fuel and energy foods, 298-301, 306-307, 313-315, 317, 320; made by green plants, 331, 340-342; used by green plants, 331; changed into fats and proteins, 341
Carbon, molecule of, 96*; in sugar and fat, 147, 163*, 301; element, 149; in fuels, 160, 173, 186, 189, 190; in paraffin, 184-186, 218; smoke from, 187*, 218*; in steel, 228; in body, 278, 279; in plants and animals, 279, 281-282, 284*; in non-living things, 281*, 284; in proteins, 302; in protoplasm, 303
Carbon dioxide, 160, 165, 167, 173; in dough, 66, 112*; in air, 86, 153, 264; in "pop," 92*; a compound, 147; from burning, 185-186*, 220*; in putting out fires, 210*-211, 213*; from animals, 264; from plants, 267; test for, 278; in animals and plants, 281; from non-living things, 283; used by green plants, 331, 338-342; in food cycle, 350*
Carbon monoxide, 86, 160, 173, 186
Carbon tetrachloride, 93, 122, 124, 211, 213*
Caterpillar, 46, 50
Cellophane, 146
Cells, in living things, 54, 270-272*, 273*-276, 283; in protozoans, 54-55; in algae and fungi, 65; of body, 274, 292-294; parts of, 274-275*, 276; root, 275*, 335*, 352*; how food and oxygen get to, 296*; compounds made in, 296; use of proteins by, 303; food stored in, 320-321; in water-carrying tubes, 336*, 337; in leaves, 338*, 339*, 340-342
Centigrade thermometer, 116*
Centipede, 44, 45*, 47, 50
Characteristics, of animals, 34-55; of plants, 56-70; of materials, 80-83, 85-86, 89-90
Charcoal, 119, 160, 173, 188*, 190
Chemical analysis, 278
Chemical change, examples of, 142*-143*, 145*; how to recognize, 155-162*, 163*; caused by heat, 160-162, 167, 179*; controlling, 164-166*, 167-170*; caused by dissolving, 165-167; caused by light, 168-169*; explained by molecular and atomic theories, 171-174; kinds of, 172, 173*, 174*, 175*, 176*; burning and oxidation as, 182-184*, 185, 186*, 187*, 195*, 203*; elements in, 278; in digestion, 294-295; made by plants, 340, 342; photosynthesis as, 342-343; decay as, 349
Chemical equation, 172, 173*, 174
Chemical formula, 149, 151, 152, 171, 172
Chemical symbol, 149, 150, 172
Chemicals, in matches, 194; for extinguishing fires, 210; made by protoplasm, 293; to regulate body, 293, 303-304; in digestion, 294-295
Chemists, 5*, 14, 20*
Chest, 29*, 38
Chimney, 196-197
Chitin, 45, 47
Chlorine, 149, 152, 171, 281*, 303
Chlorophyll, 63, 267, 273, 328, 339-341*, 342, 345, 346, 348
Circuit, 239, 240
Clam, 35, 48*, 49, 50, 53
Classification, of animals, 34-55; of plants, 56-70; plan of, 70-73; of living things, 262
Clay, 85, 153
Climate, 13, 268
Club moss, 61*, 62
Coal, made from ferns, 60; temperature from fire of, 119; carbon in, 186, 189-190, 284; compounds in, 186; fuel, 188-190, 215; bituminous and anthracite, 188*, 189*-190, 192; gas, 192, 221*; kindling temperature of, 193; regulating fire of, 198*, 199, 202; energy in, 215*, 291; conserving, 217-220
Cobalt, 229, 237, 304
Codfish, 312*, 358
Coke, 167, 188*, 190, 191
Colony, 53; of algae, 63; of fungi, 65; of social animals, 353*, 354*, 355*, 356*
Combination, 172-173*
Combustible materials, 188, 193, 195-196, 198, 205, 206, 208
Combustion, 179*, 184*, 186*, 195*, 206, 209*
Community, of people, 328-330; of plants and animals, 328-330, 349; struggle for existence in, 329, 358-361; balance of numbers in, 358-365; conservation of living things in, 365
Compass, 224*, 226, 227, 242*-249, 250*, 258*
Compounds, elements in, 147-148*, 152, 171, 277; in body, 147*; common, 151-152*, 154*; pure, 153; molecules in, 171-173*, 174*; of oxygen, 183; paraffin, 184; in fuels, 186, 189; in animals and plants, 277, 280*-282; chemical analysis of, 278; made by protoplasm, 292-293, 296; starch and sugar as, 331; mineral, 332; nitrogen, 351
Concrete, 145, 155*, 159
Condensation, 104*, 105*, 126, 127*, 128*, 129*, 130*, 132*, 133*, 137, 138*, 139*; explained by molecular theory, 137

Cones, 56*, 57*, 58
Conservation, of fuels, 215-217*, 218, 219*-220; of living things, 365
Contraction, 109, 110*-113, 114*, 115*, 134
Cooling, materials, 104*-105*, 107-110*, 111-114*, 115*, 116*; changes of state caused by, 119*, 126-127*, 128*, 129*, 130*-131*, 132*-133*, 138*-139*; effect on evaporation, 124*, 137*; effect on molecules, 134-137
Copper, 119, 149*, 155-157, 173-174, 303; sulphate, 99*, 174, 285*
Coral, 53, 263, 280*
Cork, 270-271, 274
Corn, 19, 20*, 21*, 58, 59*, 66, 267, 335*, 336*
Cosmic rays, 10
Cotton, 57, 80, 146
Crab, 44, 45*, 47, 263
Crayfish, 44, 45*, 47, 69*, 265*
Cricket, 44, 46
Crops, soil for, 19-22; rotation of, 351
Crustaceans, 45*, 47, 69*, 326*
Crystals, 89, 129, 162*, 283-284*, 285*
Cuttlefish, 48, 50, 69

Daddy-longlegs, 44*, 46
Damper, 199*, 202*
Dandelions, 59, 268
DDT, 364
Decay, 66, 349, 350*
Decomposition, 173-174*
Deficiency disease, 307-311
Diaphragm, 38
Diet, 313*, 314, 316*, 317*, 323*
Digestion, 55, 281, 294*-296
Digestive glands, 294*, 295
Digestive juices, 294, 295, 303
Dinosaur, 40, 60
Dipping needle, 245, 246*, 247, 259*
Diseases, worm, 51-52; protozoan, 55; fungi, 66, 345; virus, 285; goiter, 304; deficiency, 307-311
Distillation, 127-128*, 132, 191*
Dodder, 346*
Dog, 35, 38, 72-73*, 263, 265, 270
Draft, 197, 199*, 202*, 220*
Duckweed, 57
Dust storms, 364

Earth, problems about, 13, 25; shape of, 23; early beliefs about, 23-24; as magnet, 246; magnetic poles of, 246-249*; axis of, 247; geographic poles of, 247, 249*
Earthworm, 49*, 51, 329*
Eel, 42
Eggs, 29*, 315*, 358*, 360
Electric current, 83, 156, 174, 206, 209-211; to make things burn, 194-195, 207*; for heat, 219; in making magnets, 227, 236-240
Electric motor, 249
Electric spark, 199, 206
Electromagnet, 10, 225*, 227, 239-240*, 241*, 257*
Electron, 27; microscope, 27*, 96, 285
Elements, examples of, 146; in compounds, 147-148*, 152, 173*-174*, 175*; in body, 147*, 278-279*, 280, 303-305; some common, 149*; useful, 150*; pure, 153; tests for, 156-157; atoms in, 171-173*, 174*; in living things, 277-280*; in protoplasm, 278, 282, 303; on earth's surface, 281*; in nonliving things, 284-285; in carbohydrates and fats, 301; in proteins, 302
Energy, and force, 14, 291; atomic, 14, 216, 220; sources of, 215*, 292*-293*; from sun, 216, 341, 345; in fuels, 291-292, 298; needed by body, 291-292, 297*, 307, 320-323*; in food, 292-293, 296, 298*-299*, 300*-301*, 302, 307, 313-321; heat, 292; light, 340
Epidermis, of leaf, 338*, 339, 342
Ether, 121, 124
Ethylene glycol, 123, 124
Evaporation, of water, 90, 122*, 124*, 127*, 128*, 283, 287*; of liquids, 120-123, 125*; of solids, 121; explained by molecular theory, 136*-137*; of liquid carbon dioxide, 210
Expansion, of materials, 104*, 107*, 108-110*, 111*, 112*, 113*, 114*, 115*, 202*; explained by molecular theory, 134
Explosion, 184*

Fahrenheit thermometer, 39, 116*
Faraday, Michael, 4*
Fats, 131; food changed into, 145, 320-321; in milk, 153, 314; fuel and energy foods, 298-301*, 306-307, 313-320; elements in, 301; from green plants, 331-332, 341
Ferns, 60*, 61*, 62, 63, 268
Fertilizer, 21*, 22, 65
Fibrous roots, 333, 334*
Filter, 89*, 99
Fire, 179*, 184*, 186*; as chemical change, 159; making, 178*, 180-181*, 188-194*, 195-203*; history of, 180; heat and light from, 182-185, 188; oxygen for, 182-185, 196-198, 218; smoke from, 186, 188, 190, 197, 218; causes of, 195*, 205*, 207*; regulating, 197-198*, 199*-202*; preventing and extinguishing, 204-207*, 208-209*, 210*, 211*-213*; forest, 204*, 214*
Fire alarms, 208*
Fire extinguishers, 209*, 210*, 211*, 212, 213*, 223*
Fish, structure of, 35, 38, 42, 72; kinds of, 35, 41-42, 69, 74; as food, 166*, 326*-327*
Flatworms, 49*, 51-52
Flea, 44, 46

Floods, 364
Flowers, 56*, 57*, 58, 59*, 67*, 337*
Fluke, 49*, 52
Fluorine, 304
Fly, 44*, 46, 265, 363*
Food, -getting by plants, 56-57, 328, 330-343*, 345-351; stored in seed, 58; chemical changes in, 145, 159, 166*-167; needed by living things, 265, 267, 290, 297*, 328, 345; used by protoplasm, 276, 292-293; needed by body, 288*-289*, 291*, 296, 313*; fuel and energy, 292-293, 298*-299*, 300*-301*; body-building, 292-293, 302-305; digestion of, 294-296; carried by blood, 294-296*; oxidation of, 296, 298, 301-302, 317; kinds of, 298-299*, 300-304*, 305*-312*, 315*; protective, 304, 307-308*, 309*, 312*; composition of, 306; experimenting with, 308*-309*; how to choose, 313-316*, 317*-322, 323*; calories in, 318-319; stored in cells, 320-321; how to make best use of, 322; -getting by animals, 345-346; cycle, 349-350
Force, and energy, 14, 291; lines of, 224*, 233-234, 246, 252; magnetic, 225*, 229*, 230-231*, 232-234*, 235*, 240*; field of, 233, 236-237, 245
Forest, 189, 215; fires, 204*, 208, 214*
Freezing, 110*, 116*, 117, 131, 135
Friction, 167, 194, 206
Frog, 22-23, 35, 40*-41, 42, 360
Frost, 129, 138*
Fruits, 58, 59, 299, 305, 311, 314
Fuels, 60; composition of, 186; burning of, 186-187; comparison of, 188*, 189-192; solid, 188-190; liquid, 191-192; gas, 192; regulating in fires, 198*, 199*, 202*; cutting off to extinguish fires, 208; conservation of, 215, 216*, 217*, 218*, 219*, 220*; peat, 222*; used by non-living things, 283; heat energy in, 291, 292, 298; foods as, 292, 296, 298*, 299*, 300*, 301*, 302, 317, 320
Fungi, 64*, 65-66, 268, 345*, 346-347, 348*
Furnace, blast, 119, 167; chimney on, 197; regulation of fire in, 198-200, 202
Fuse, electric, 206

Galileo, 6, 7, 8*
Gases, 78*-79*; characteristics of, 84*-86*, 87*, 95, 107, 116, 171; in solution, 91-92; molecules in, 97*-99, 103*, 136-137; liquids changed to, 102*, 120-123, 144, 148; heating and cooling of, 108-113, 136-137; solids changed to, 121-122; changed to liquids, 126-129, 132; changed to solids, 129, 132; elements, 149; in air, 153; from chemical changes, 165, 167, 173; as fuel, 186, 192; natural and manufactured, 188*, 192; coal, 190, 221*; bottled, 192; transportation of, 192*; from burning, 196; burner, 199-201*, 202; extinguishing fires from, 208; available for fuel, 215-216; how to conserve, 217-220
Gasoline, fuel, 81*, 187-188*, 192, 205-206; as solvent, 91, 93; evaporation of, 121; from petroleum, 191*; extinguishing fires from, 209-211; from coal, 221*; energy in, 291
Geologists, 13*
Germs, 26, 27, 66
Gilbert, Sir William, 227*
Gills, 41, 42, 49, 264
Glands, 38, 294*, 295, 304
Glass, 80, 105*, 110-113, 118, 119, 194, 219*
Goiter, 304
Gold, 97, 146, 149, 173
Gopher, 69
Grain, 58, 219, 299, 315
Grasses, 56*, 57, 58
Grasshopper, 44*, 46; plagues of, 362*
Gravity, as stimulus, 269
Ground pine, 61*, 62
Growth, of plants, 19-22, 65, 268*-269*, 331, 360; of animals, 41, 265; of living things, 276, 284-285, 292-293; of non-living things, 283, 284*, 285*
Grubs, 46, 50
Guard cell, in leaf, 338*, 339*
Gyrocompass or **gyroscope,** 248, 249

Heart, 30, 38, 296*
Heat, from oxidation, 145, 179*, 182-184*, 185-186*, 188, 195*, 207*, 209*; in chemical change, 167; from fuels, 188*, 189-192, 215*; conserving, 218-219; from the sun, 220; from oxidation of food, 292, 296, 298, 301-302, 317, 320; energy, 292
Heating, effect on materials, 104*-105*, 107*-111*, 112*, 113*, 114*, 115*, 116*, 139*, 160, 161-162, 164, 167, 173; changes of state caused by, 116-119*, 120-122*, 123*, 124*, 125*, 127*, 128*, 131*; and evaporation, 121-122; effect on molecules, 134-136*, 137*; effect on magnets, 253
Helium, 28, 29, 129, 149, 171
Hellbender, 42
Hibernation, 39, 41
Hooke, Robert, 26*, 270, 274
Hookworm, 51
Horsetail, 61*, 62
Hydra, 53
Hydrochloric acid, 174*, 281, 303
Hydrogen, 160, 173; boiling point, 129; in water, 147-148, 152, 156, 159, 171, 278, 303; in sugar and fat, 147, 301; element, 149; atoms in, 171; in paraffin, 184-186; in fuels, 186; in body, 278-279*; in plants and animals, 279, 282; on earth's surface, 281*; in proteins, 302; in protoplasm, 303

Ice, 109, 110*, 116, 121, 130, 135
Incombustible materials, 188
Influenza, 27, 285
Insects, kinds of, 35*, 44*, 74*; structure of, 45*, 46, 68; breathing of, 46; larvae, 46, 69; food for many-legged animals, 47; food of, 345; social, 354*, 355*, 356*; food for birds, 361, 365; plague of, 362*; poisons, 364, 365
Intestines, 38, 294*, 295
Invertebrates, 32*, 33*, 35*, 43, 44*, 45*, 46*-48*, 49*-52*, 53*, 54*, 55, 69*, 74*
Iodine, crystals, 93, 94; test for starch, 157, 278; in body, 303-304; in foods, 304-305
Iron, melting, 119; rusting, 145, 156, 164-165, 172, 182-183; element, 146, 149*, 153; ore, 146, 167, 190, 227; in body, 147; heated with sulphur, 161-162, 164, 167, 172; sulphide, 162, 164, 167, 172-173*; oxide, 165, 172, 183; atom, 171; sulphate, 174; magnetic material, 226, 228, 243, 251; in permanent magnets, 236-237; in temporary magnets, 238-239; on earth's surface, 281*; in blood, 303; in foods, 304, 314-315

Janssen, Zacharias, 25
Jellyfish, 53, 69
Jet propulsion, 50
Jupiter, planet, 25

Kindling temperature, 193-195, 196, 198, 208
Kerosene, 93, 188*, 191, 192, 197, 200

Laboratory, 4*-5*, 6, 15*, 17*, 20*, 27*-28*, 29*
Larva, 46, 50, 69
Lead, 119, 131, 149, 172, 173; oxide, 172, 173*; monoxide, 173
Leaves, of seed plants, 57-58; veins in, 58-59, 67*, 337-338*; of plants without seeds, 60*-61*, 62; blueprint of, 169*; evaporation of water from, 287*; carbon dioxide in, 331; food made by, 336, 338-343; structure of, 337*, 338*, 339*; cells in, 338-342
Leeches, 49*, 51, 360
Legumes, 351, 352*
Lens, 24
Lice, 44, 46
Lichen, 347-348*
Light, as cause of chemical change, 168-169; from burning, 179*, 182-184*, 185-186*, 188, 195*, 209*; stimulus, 266, 269; needed by plants, 340-342; energy, 340
Lignite, 188*, 215*
Lime, 47, 53, 158
Limestone, 53, 167, 172
Limewater, 158, 278
Line of no variation, 247, 248*
Linnaeus, Carl, 71*-72
Lippershey, 24
Liquids, 78*-79*; characteristics of, 85*, 87*, 95, 107, 116; in solution, 89-90, 93-94; insoluble in water, 91*; as solvents, 92*-95*, 100*, 101*, 102*; molecules in, 97*-99*, 134-137; effect of heating and cooling on, 108-113, 134-137; evaporation of, 120-123; boiling points of, 124; gases changed to, 126-129, 132; changed to solids, 130-132, 144; chemical changes caused by, 165-167
Litmus paper, 157, 158
Liver, 52, 294*
Liverworts, 62-63, 64*
Living things, problems about, 15; classification of, 34-73, 262; cells in, 54-55, 270-276, 283; dependent on green plants, 56, 328, 349; decay of, 66, 349; likenesses in, 263-283; food needed by, 265-267, 290, 297*, 328, 345; growth of, 265, 268, 284; organs in, 270; materials in, 277-282; elements in, 277-279; compounds in, 280-283; non-living things different from, 283-285; in a community, 328-330, 349, 358; struggle for existence among, 329, 358-359; dependent on each other, 328-365; balance of numbers among, 358-365; conservation of, 365
Lizard, 37*, 39, 40, 260*-261*, 277*
Lobster, 44, 45*, 47
Lodestone, 227, 228*, 236
Lungs, 30, 38, 39, 41, 42, 264, 294*, 296

Magellan, 307
Maggot, 46, 50
Magnesium, 183, 281*, 304; oxide, 183
Magnetic field, 233, 237-240; of earth, 246, 256*
Magnetism, 224-259; theory of, 251-254
Magnetite, 227
Magnets, 10, 161-162, 226, 227; and magnetic materials, 224*-225*, 228-229*, 231*, 234*-235*, 240*-241*, 255*-258*, 259*; lines of force of, 224*, 233-234, 246, 252; in compasses, 224*, 242*-246*, 247-250*, 258*-259*; force of, 225*, 229*-231*, 232-234*, 235*, 240*; shapes of, 228*; what they can do, 228-234; alnico, 229*, 237, 255*; poles of, 232-233, 243-245, 251-254; field of force of, 233, 236-238, 245; how to make, 236-240; permanent, 236-237, 238, 242; temporary, 238-240; and non-magnetic materials, 238; earth as, 246; molecules in, 251*-254
Magnifying glass, 25, 26, 51
Mammals, 35*, 36*, 38, 72-73*, 74*
Manganese, 304
Many-legged animals, 45*, 47
Matches, 182, 193-194*
Materials, problems about, 14, 78*-79*; atomic energy in, 14, 216, 220; in sun, 28; likenesses and differences in, 80, 81*-84, 85*-87*;

soluble and insoluble, 88-91*, 92*-95*, 99*-100*, 102*; molecules in, 95-97*, 98-99*, 103*, 134, 171-174; atoms in, 96*, 171-174; water-repellent, 102*; physical changes in, 104*-105*, 107*-110*, 111*-112*, 113*-114*, 115*, 116*-119*, 120-122*, 123*-124*, 125*-127*, 128*-129*, 130*-131*, 132*-133*, 134-136*, 137*-138*, 139*, 144*; chemical changes in, 142*, 143*-145*, 146-162*, 163*-166*, 167-170*, 171-173*, 174*-175*, 176*; elements and compounds in, 146-147*, 148*, 149*-152*, 153-154*; raw, 146*; synthetic, 146*; pure, 153; tests for, 155-158; properties of, 155*-156, 159*; combustible and incombustible, 184-186, 188, 193, 195-196, 198, 205, 208; fireproof, 214*; insulating, 219*; magnetic, 224*-225*, 228-229*, 231*, 234*-235*, 240*-241*, 255*, 258*-259*; non-magnetic, 228, 230; magnetized and unmagnetized, 251*, 258*; in living things, 275*, 277-279*, 280*-283; chemical analysis of, 278; on earth's surface, 281*; needed by body, 292-293, 307; supplied by food, 292-293, 302-305, 307, 313; used by green plants, 330-337, 349-351

Matter, 83-84; states of, 78*-79*, 85*-87*, 97*, 116; molecules in, 96-99

Measuring worm, 69

Melting, 105*, 116*, 117, 119*, 131*, 135

Mercuric oxide, 148, 152, 159, 173, 174*, 183

Mercury, -vapor lamp, 15*; in thermometer, 97, 111; evaporation of, 121; boiling point, 124; freezing point, 131; element, 146, 148, 149, 152, 159, 173; in mercuric oxide, 183

Meteorologists, 13*

Microscope, development of, 25, 26*-27*; electron, 27*, 96, 285; use of, 30, 44, 54, 89, 270-272*, 273*-275*, 338, 347, 352*

Migration, 39

Milk, glands, 38; suspension, 90; chemical change in, 145; as food, 309*, 311, 314-315*; irradiated, 314

Milkweed, 359*

Millipede, 45*, 47, 50

Minerals, in plants, 20-22, 331-337, 344*; in soil, 21*, 332, 335, 340, 351; helium in, 29; in coal and wood, 186; as foods, 302, 304, 307, 313; needed by body, 303-305; in foods, 303-305*, 306, 314-315*

Mistletoe, 346*

Mite, 46

Mixture, 86, 88, 90, 153, 154*

Mold, 64*, 65, 66, 346, 347

Molecular theory, 95-99, 134-137, 171-174

Molecules, in matter, 96*, 97*-99*; atoms in, 96*, 171-174; in air, 103*; effect of heating and cooling on, 134, 135*, 136*, 137*; in elements and compounds, 148*, 173*, 174*; during chemical change, 172-174; as magnets, 251*-254

Mollusks, 48*-50, 69*

Mosquito, 44, 46, 91*, 358

Mosses, 62, 63, 64*, 268

Moth, 44*, 46, 358*, 363*

Mud puppy, 40*, 42

Muscles, 14; in diaphragm, 38; of birds, 39; of mollusks, 48; food changed into, 145; cells in, 272, 292, 296; regulated by chemicals, 293

Mushroom, 64*, 65, 75*, 346

Nautilus, 48

Neon, 28*

Nerve, cord, 36; cells, 272

Niacin, 309

Nickel, 149*, 229, 237

Nitrogen, in soil, 21*, 351; in air, 86, 153, 264, 351; element, 149; molecule of, 171; in living things, 278-279*, 280*, 282; in proteins, 302, 332, 351; in protoplasm, 303

Non-living things, 262-263, 283-285

Nucleus, 272*, 273*, 274, 275*

Nylon, 146

Oats, 58, 66

Octopus, 48*, 50

Odor, 265, 266

Oil, soluble and insoluble, 91*, 93; evaporation of, 121; to prevent rusting, 165; wells, 178*, 191-192, 216*-217*; compounds in, 186; fuel, 188*, 191-192; crude, 191*; in spontaneous combustion, 195, 206; burner, 199-200*, 202; combustible material, 205; extinguishing fires from, 208, 209*-211; supply available for fuel, 215*-216; gusher, 216*; how to conserve, 216*, 217*-220; liquid fat, 300

Organ, 270, 273

Ostrich, 39, 271

Owl, 346, 361*

Oxidation, 183-184*, 186*-187*, 195*, 203*; of food, 292, 296, 298, 301-302, 317, 320

Oxide, 183, 184

Oxygen, in air, 86, 153, 167, 205, 264; in water, 147-148, 152, 156, 159, 171, 278, 303; in foods, 147, 301-302; in compounds, 148, 152, 159, 165, 172-174; an element, 149; molecule of, 171; in burning, 182-186*, 187*, 195-203*, 208, 212, 218; in plants and animals, 264, 267, 279, 282; in body, 278-279*; on earth's surface, 281*; used by non-living things, 283; carried to cells, 296; to use food, 296, 298; in protoplasm, 303

Oyster, 48, 49, 50, 53, 263

Paint, 93, 95*, 102*, 158, 165, 176*

Paper, 57, 58, 80

Paraffin, 131, 184, 185, 186*

Parasites, animal, 49*, 51-52, 54*; plant, 64*, 66, 345*-346*, 347, 360
Peas, 59, 351
Peat, 188*, 215*, 222*
Pellagra, 308, 310
Penguin, 37*, 39
Penicillin, 64*, 66
Perspiration, 280, 281
Petal, 58, 59, 267
Petroleum, 191*, 192, 284; coke, 191
Phosphorus, in soil, 21*; in body, 147, 279*, 303, 314; on earth's surface, 281*; in proteins, 302; in foods, 304, 314, 315
Photosynthesis, 342-343*, 345
Physical change, 144
Physicists, 5*, 14, 15*
Plague, 362*
Planets, 25; temperature of, 29
Plants, diseases of, 16*, 345*; growth of, 19-21, 65, 268*-269*, 331, 360; minerals and water needed by, 20, 22, 280-282, 332-337; kinds of, 32*-33*, 67*; classification of, 56-70, 262; with seeds, 56*, 57*-59*, 67*; without seeds, 60*-61*, 62-64*, 65-66; chlorophyll in, 63, 328, 339-341*, 342, 345-346, 348; parasites in, 66, 345*-346*; chemical changes in, 145; activities of, 260*-261*, 266*-268*, 269*, 276*; likeness to animals, 260*-261*, 263*, 273*, 275*-276*, 279*; organs in, 270, 272; cells in, 271-273*, 274-275*, 335*-336*, 338*-339*, 352*; one-celled, 271-272; elements in, 277-280*; compounds in, 280*-282; sugar from, 300*; fats from, 301*; community of, 326*, 328-330, 358, 359*-363*; need food, 328, 331, 345; food made by green, 328, 330-343*, 345; products from, 328; living things dependent on green, 328, 345-346; dependent on other living things, 328; struggle for existence among, 329-330*, 358-361; materials used by, 330-337, 345, 349-351; use of carbon dioxide by, 331, 338-341; and animals dependent on each other, 329*, 345-348*, 349-350*, 351-356; roots of, 334*, 352*; moving of, 335; water-carrying tubes of, 336*-337*, 338, 344*; food-getting by, 346-351; decay of, 349-350*; reproduction of, 57-58, 61-62, 65, 358-359; balance of, 363-365
Plastics, 119
Poles, magnet, 232-233, 243-245, 251-254; magnetic, 246-249*; geographic, 247, 249*
Porpoise, 38, 264*
Potassium, 147, 281*, 304
Potato, 314, 315*, 343*
Prediction, 126
Principle of science, 109, 110-113, 122
Problem-solving, 8, 9*-17, 18*-19*, 20*-21*, 22
Properties, of materials, 155*-156, 159*-162
Proteins, body-building foods, 302-303, 313; fuel foods, 302, 317, 320; elements in, 302, 332; in foods, 302, 304*, 306, 314-315; in protoplasm, 302-303, 305, 314; from green plants, 331, 341
Protoplasm, in living things, 274-275*, 276, 283; compounds in, 277; elements in, 278, 282; use of food by, 292-293; proteins and water in, 302-303, 305, 314; in root hairs, 335; in leaf cells, 341
Protozoans, 54*-55, 265, 326*, 356

Rabbit, 38, 364, 365*
Ragweed, 69
Rat, 38, 308*, 309*
Rayon, 146
Replacement, 174*
Reproduction, 38-39, 41, 42, 55, 57-58, 61-62, 65, 265, 268, 358-359
Reptiles, 37*, 38, 39-40, 69*, 72
Response, 266
Riboflavin, 309
Rickets, 308*, 310, 311, 312*
Rock, 262, 347
Roots, of seed plants, 57, 330; of plants without seeds, 61-62; cells of, 273*, 275*; water and minerals taken in by, 331-332; kinds of, 333-334*; hairs, 334-335*; starch carried to, 342; potato, 343*; legume, 351, 352*
Roundworms, 49*, 51-52
Rubber, 80, 93, 109, 119, 144
Rust, fungi, 66; compound, 153; preventing, 164-166*, 170*; forming, 172, 182-184*

Sac-like animals, 52*, 53
Salamander, 40, 41, 42
Saliva, 294*, 295
Salt, in solution, 89; in water, 122*, 127-128*; compound, 147; table, 152, 158; chemical, 158; in animals, 281; iodized, 305
Sand dollar, 52
Saprophyte, 347, 349
Scales, reptile, 39; fish, 42
Scallop, 48
Schleiden, Matthias, 271
Schwann, Theodor, 271
Scientific method, 22
Scientists, of long ago, 4*, 7*-8*; of today, 4*-5*, 12*-13*, 15*-16*, 17*, 20*, 28*-29*
Scorpion, 44*, 47
Scouring rush, 62
Scurvy, 307, 310
Sea anemone, 53
Sea cucumber, 52, 69*, 70
Sea horse, 41*, 42, 69*
Sea lily, 52, 70
Sea urchin, 52
Seaweed, 63, 65

Seeds, plants with, 56*, 57*-59*, 67*; growth of, 58, 267-268, 331, 359-360; one-part, 58; two-part, 59; plants without, 60*, 61*-64*, 65-66; crystal, 284*; starch carried to, 342
Segmented worms, 49*, 51
Segments, 45, 46, 47, 51
Sequoia, 57, 58, 268
Shell, egg, 39; mollusk, 48*-50, 53
Shipworm, 48, 69
Shrew, 38
Shrimp, 45*, 47
Shrubs, 57, 58
Silicon, 279, 280*, 281*; carbide, 175*
Silver, 97, 146, 149*, 162*
Skeleton, of vertebrates, 36*-37*, 40*-41*; of arthropods, 44*-45*, 46*-47; of sponges, 53*
Skin, of animals, 39, 40, 45, 52; disease, 66; cells, 292
Slime mold, 64*, 262, 263*, 285
Slugs, 48, 49, 50
Smoke, from burning, 145, 186, 188, 190, 218; controlling, 187*; carried by chimneys, 197; uncontrolled, 218*; stack, 220*
Smut fungi, 64*, 66
Snails, 35*, 48*, 49, 50, 263
Snake, 35*, 37*, 39, 40, 263, 360
Snow, 105*, 129*
Social animals, 353*, 354*, 355*, 356*
Sodium, 152, 156-157, 281*, 303; chloride, 152
Soil, minerals in, 19-21*, 22, 332, 335, 340, 351; testing, 20*-21*; enriched by bacteria, 66; a mixture, 153; acid, 158; nitrogen in, 351; effect of plowing on prairie, 364
Solids, 78*-79*, 80; characteristics of, 85*, 87*, 95, 107, 116; in solution, 89-91, 93-94; in suspension, 90, 100*; molecules in, 97*-99*, 134-135; heating and cooling of, 107, 113*-114*, 119*; changed to liquids, 116-119; evaporation of, 121-122; gases changed to, 129; liquids changed to, 130-132, 144
Solutions, characteristics of, 88-90; kinds of, 92*, 95*, 99*, 101*-102*; liquids in, 93-94; molecular theory and, 98-99; iodine, 157; evaporation of, 283; in digestion, 294
Solvents, 91*, 92*, 93-95*, 99*-100*, 101*-102*
Soot, 218
Sound, as stimulus, 265, 266
Sow bug, 47, 69
Soybean, 142*-143*, 144, 351
Space, taken up by materials, 83
Sparrow, 358
Spectroscope, 28*, 157
Spider, 35*, 44*, 46, 263
Spinal cord, 36
Spiny-skinned animals, 52*-53, 69*
Sponges, 53*-54, 279
Spontaneous combustion, 195*, 206
Spores, 60*, 61*-64*, 65-66, 75*, 268
Spots, removal of, 93-94, 122
Squid, 48*, 50
Squirrel, 38, 74*, 262, 263, 271, 284
Stains, removal of, 93-94, 122
Starch, suspension, 90-91, 99, 294; iodine test for, 157, 278; changed into sugar, 295; in foods, 295, 299*, 343*; made by plants, 331; elements in, 331; from sugar, 340, 342
Starfish, 35*, 52, 69
Stars, 13*, 28
States of matter, 78*-79*, 85*-87*, 97*, 116; changes in caused by heating, 116-119*, 120-122*, 123*-124*, 125*, 127*-128*, 131*, 136*-137*, 139*; changes in caused by cooling, 119*, 126-127*, 128*-129*, 130*-131*, 132*-133*, 138*-139*
Steam, 123, 126-128, 132, 137, 144, 174, 209, 219
Steel, expansion and contraction of, 112; melting and molding, 119*; rusting of, 156; magnetic material, 226, 228, 243, 251; alloy, 228; in permanent magnets, 236, 237
Stems, of plants, 57, 61-62; growth of, 269, 331; water-carrying tubes in, 336*-337; starch carried to, 342
Stethoscope, 30
Still, 127-128*, 191*
Stimulus, 260*-261*, 264*, 265*-266, 268-269, 277*, 284
Stoker, 198*, 202*
Stomach, 38, 294*-296, 303
Stomate, 338*, 339*
Stove, 197, 198-199*, 200, 205
Structure, of vertebrates, 32*-33*, 34, 35*, 36*, 37*-40*, 41*-42, 69*, 73*-74*; of invertebrates, 32*-33*, 35*, 43-44*, 45*, 46*-48*, 49*-52*, 53*, 54*-55, 69*, 74*; of plants with seeds, 56*, 57*-59*, 67*; of plants without seeds, 60*, 61*-64*, 65-66; living things grouped according to, 71-73
Struggle for existence, 329, 330*, 345*, 346*, 358-361*, 363*
Sugar, cane, 58, 299; physical change in, 91, 144, 163*, 294; a compound, 147, 153; in body, 147; in milk, 153; chemical change in, 163*; starch changed into, 295; in foods, 299; beet, 299; made by plants, 300*, 331, 342; food stored in cells as, 320; elements in, 331; starch made from, 340, 342
Sulphur, mining, 131*; element, 146, 149, 171; in body, 147; when heated with iron, 161-162, 164, 167, 172; on earth's surface, 281*; in proteins, 302; in hair and nails, 303
Sulphuric acid, 163*, 211
Sun, relation to earth, 25, 28; helium in, 28; energy of, 216, 341, 345; heat from, 220; ultraviolet rays from, 311; lamp, 311, 314
Suspension, 90, 91, 99, 100*

Tadpole, 41, 360
Tapeworm, 49*, 52
Taproot, 333, 334*
Teeth, 279, 281, 303
Telegraph, 10
Telephone, 11*
Telescope, 12*, 24; Mt. Wilson and Palomar Mt., 25
Temperature, measured with thermometer, 29; of animals, 38, 39, 41; changes in, 112-113; freezing, 116, 130, 131; melting, 117; needed to work with certain materials, 119; from the sun, 119; and evaporation, 121-122; boiling, 123-124; controlling water vapor in air, 128; and condensation, 129; in chemical change, 167; body, 296
Termite, 55, 354, 356
Terrarium, 76*-77*
Tests, for diseases, 16*, 17*, 345*; soil, 20*-21*; for freshness of eggs, 29*; for gasoline, 81*; flame, 156; litmus, 157-158; iodine, 157, 278; for paint, 176*; limewater, 278
Theory, 96; molecular, 95-99; atomic, 171; of magnetism, 251-254
Thermometer, 29; clinical, 29-30; Fahrenheit, 39, 116*; mercury, 97, 111; Centigrade, 116*
Thermostat, 202*
Thiamin, 309
Thorax, 38, 45, 46, 47
Thyroid gland, 304
Tick, 44*, 46
Tin, 149*
Titanium, 281*
Toad, 40*, 41, 69; horned, 69*
Tortoise, 39, 40
Trees, with cones, 56*, 58; sequoia, 57, 58, 268; seed plants, 57, 68; with flowers, 58, 59; oak, 72, 262, 263, 268, 269*, 271, 272; size of, 268; cells in, 273, 274; catalpa, 363*
Trichina, 49*, 51
Tube worm, 51
Turpentine, 58, 93, 124
Turtle, 37*, 39, 40, 69, 360

Ultraviolet rays, 29*, 311, 312*, 314
Underwriters' Laboratories, Inc., 212

Van Leeuwenhoek, 26*
Vegetables, 57-59, 304, 305, 309*, 311, 314
Veins, in leaf, 58, 59, 67*, 337, 338*
Venus's flytrap, 266*
Verification, 22
Vertebra, 36
Vertebrates, 32*-33*, 35*-36*, 37*-40*, 41*, 42, 69*, 72-73*, 74*
Veterinarian, 17*
Vinegar, 91, 157
Virus, 285
Vitamins, in foods, 305*, 310-311, 314-315*; discovery of, 307-309; needed by body, 307-311, 313; protective foods, 307-308*, 309*, 312*; from green plants, 331
Volume, of materials, 82, 85, 86, 107-113

Wasp, 44, 46, 354*, 355*
Water, germs in, 26; animals in, 38, 41-42, 47-48, 52-55; breathing in, 42; plants in, 63; characteristics of, 80-84; liquid, 85; solvent, 91*, 93, 99*-100*, 101*, 294; air in, 92; soda, 92*; molecules, 99*; -repellent material, 102*; effect of heating and cooling on, 104*, 109-110*, 111, 116, 122*-123*, 124*, 127*-128*, 136*-137*, 139*; boiling point, 116*, 123-124, 126, 219; freezing point, 116*, 130-131; evaporation, 120, 128, 287*; changing to steam, 123, 126-127, 209, 219; distilled, 127-128, 132; change in state of, 144-145, 174; compound, 147-148, 152, 171, 174*, 278; in body, 147, 305; physical properties of, 155; chemical properties of, 156; in sugar, 163*; in chemical changes, 165-167, 174; incombustible material, 188; in fighting fires, 209-210, 214*; energy from moving, 215*, 219; chemical analysis of, 278; in animals and plants, 280-282; in blood, 280; in perspiration, 280-281; as food, 302, 313; in protoplasm, 302-303; hydrogen and oxygen in, 303; minerals in, 305; in foods, 305*-306, 314; in soil, 329*; from green plants, 331; used by green plants, 331-337, 340-342; in food cycle, 350*
Water-carrying tubes, 57, 61, 336*-337*, 344*
Water flea, 47, 69
Water vapor, 104*-105*, 126-127*, 128*-129*, 130*, 132*-133*, 136-138*, 139*, 153, 185-186*
Wax, 131, 354
Weather, 13*, 20
Weeds, 57, 58
Weight, of materials, 83
Wheat, 19, 58, 66, 267; whole-, 307, 315
Wood, 57; characteristics, 80-85; temperature from fire of, 119; chemical change in, 144-145*, 159-160, 173; physical change in, 144*; properties, 160; compounds, 186; fuel, 188*-189, 198, 215*, 219; charcoal from, 190; available for fuel, 215; alcohol, 219
Wool, 80, 146
Worms, 49*, 50-52, 329*

X-ray machine, 29*, 30, 96*

Yeast, 64*-66, 268, 346

Zero-degree line, 247, 248*
Zinc, 149*; chloride, 174*

Acknowledgments

The publishers express their appreciation to the following for permission to reproduce the photographs on the pages indicated: Abbott Laboratories, 5; reproduced from *What's New,* published by Abbott Laboratories, 320; Acme Photos, 13 (left), 115 (bottom), 122, 138, 222, 362; Aermotor Co., 292 (left); Aero Service Corp., 256; Air Force Photo, 214 (left); American Binder Co., 255 (left); American Bottlers of Carbonated Beverages, 92 (right); *American City Magazine,* 100; American District Telegraph Co., 208 (left, center); American Fixture & Mfg. Co., 149; *American Forests,* 214 (bottom right); American-LaFrance-Foamite Corp., 213 (top left, bottom left), 223 (center); American Museum of Natural History, 353; American Optical Co., Scientific Instrument Division, 28 (left); American Telephone & Telegraph Co., 11, 114; Bacharach Industrial Instrument Co., 220; Bastian-Blessing Co., 92 (left); Bausch & Lomb Optical Co., 27 (left, center); Bell Telephone Laboratories, 284; W. A. Bentley, 129; Bettmann Archive, 26 (right), 104 (bottom left), 291; Bituminous Coal Institute, Educational Dept., 187, 189; Black Star, 27 (right); Boka Mfg. Corp., 223 (bottom); Devereux Butcher, 348; Capital Press Service, 102 (left); Carborundum Co., 175; Cardox Corp., 210; Century Photo, 4; Lynwood M. Chace, 354, 355, 356, 359; Chicago Natural History Museum, 346 (left); *Chicago Sun Times,* 218; Club Aluminum Co., 149; Communicable Disease Center, Atlanta, Ga., 91; Curtis Companies, 144; W. S. Darley & Co., 246 (right); Paul S. Davis, 76, 77; Deere & Co., 293 (right); Adapted from The Diamond Match Co., 194; Dow Chemical Co., 159 (left); *Du Pont Magazine,* 102 (right), 146 (left), 176; Eastman Kodak Co., 96, 162, —Distillation Products, Inc., 105; Edwards & Co., 208 (right); *Engineering and Mining Journal,* 13 (right); Eriez Mfg. Co., 235; Ewing Galloway, N. Y., 12, 119, 130, 139 (right), 142 (top), 166 (bottom left), 178 (right), 225, 298 (top), 312, 327; *Farm Journal,* 95 (right); *Farm Quarterly,* 297 (left), —Australian News & Information Bureau, 365, —Joe Munroe, 20, 330; Fitz Water Wheel Co., 292 (right); Ford Motor Co., 111 (left); Freeport Sulphur Co., 131; General Biological Supply House, 336 (right), 338 (top); General Electric Co., 229; Glidden Co., 143 (left); Gorham Sterling, 149; Hagen's Fish Market, 327 (center); James G. Harlow, courtesy of *Nature Magazine,* 277; Harter Corp., 297 (right); Lilo Hess from Three Lions, 329; Henricks Hodge, 266, 346 (right); J. M. Hood, courtesy of *Nature Magazine,*

265; Illinois Bell Telephone Co., 257; Inland Steel Co., 29 (right); International News Photo, 9; International Nickel Co., 184 (right); Frances L. Jewett, 341; Leon Keinigsberg: Copyright: *Chicago Tribune,* 260 (top), 261 (top); Keystone View Co., 339 (left); Walter Kidde & Co., 213 (bottom right); A. Kreamer, 149; Harold M. Lambert, 104 (top left), 115 (left), 166 (top, bottom right), 179; *The Lamp,* Standard Oil Co., N. J., 191; By *Life* photographer Fritz Goro copyright *Time,* 224 (right), 231, 234; *Life* copyright *Time,* 358; Lionel Corp., 241; Malanco, Inc., 219; Marine Studios, Marineland, Fla., 264; Karl Maslowski, 361; Meyers, Oklahoma City, 216 (left); Minneapolis-Honeywell Regulator Co., 202 (left), —adapted from, 202 (right); Monsanto Chemical Co., 166 (center); Montgomery Ward, 199; National Board of Fire Underwriters, 207; National Bureau of Standards, 195, 275 (left); National Dairy Council, 304, 305, 315, 316, 317; National Paint, Varnish and Lacquer Assoc., 95; National Safety Council, 205, 211; *The Open Road for Boys* —Theron Lowe, 203; Parade Publication, 224 (left); A. C. Parsons, courtesy of *Frontiers,* 363; Phelps Dodge Refining Corp., 285; Edward Probert, 260 (bottom), 261 (bottom); Pyrene Mfg. Co., 213 (top right), 223 (top); Revere Copper and Brass Inc., 149; Rival Mfg. Co., 255 (right); Ruberoid Co., 146 (right); *Science Illustrated* —Hans Basken, 159 (right), —George S. Heilpern, 214 (top right); Science Service, 209; *Soybean Digest,* 142 (top-second row, center, bottom); Hugh Spencer, 263, 335 (left); Standard Oil Co. (N.J.), 81, —Corsini, 216 (right), —Parks, 155, —Rosskam, 217; Sunbeam Corp., 149; Taylor Instrument Companies, 242, 246 (left); The Texas Co., 178 (left); Adapted from Timken Silent Automatic Division, 200; U. S. Beet Sugar Assoc., 293 (left), 334 (left); U. S. Bureau of Human Nutrition and Home Economics, 308, 309, 321; Adapted from U. S. Coast Guard Photo, 128 (right); U.S.D.A. Bureau of Plant Industry, 16, 345; U.S.D.A. Forest Service, Forest Products Laboratory, 145; U.S.D.A. Photo by Madeleine Osborne, 17; U.S.D.A. Production and Marketing Administration, 142 (center right); U.S.D.A. Soil Conservation Service, 334 (right); U. S. Steel Corp., 240; Univ. of Calif., Division of Plant Nutrition, 344; Vizerak Co., 255 (center); Vulcan Stamping & Mfg. Co., 149; Westinghouse Electric Corp., 15, 29 (left); Wheat Flour Institute, 28 (right); White Motor Co., 192; Wide World Photos, 24, 25, 113, 139 (left), 184 (left).

The drawings were made by Robert E. Celander, Raymond E. Craig, Alex Palmer, and Arnold W. Ryan.

9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 58 57 56 55 54

E. P. S. B.
STRATHEARN
JR. HIGH SCHOOL
LIBRARY BOOK
No..... .....

1 C